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HOW THE ENGINEER CAN HELP BUSINESS

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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How the Engineer Can Help Business[1]

By R. H. Grant[2]

IT would be of little avail for me to tell what the engineer can do to help business as it stands today unless we agree on how business stands today. I believe that we can look forward into the future with optimism. Let us examine the case and see whether we have any grounds for coming to that conclusion. To do that we must go back to 1914. Then this Country was having a hard time to sell goods. At that time I was sales-manager of the National Cash Register Co. We had a powerful selling force but were having a difficult time to dispose of our product in the usual quantities because the retail merchants to whom we sold were in trouble. A new tariff law had just become effective and the Country was being flooded with goods from abroad. We could not keep our own factories running. In October 1913 we began to find a sales resistance such as we had not found since 1907.

In 1915 the condition changed completely. The countries of Europe were engaged in war and stopped sending goods here. An artificial tariff wall was set up, the strongest we had ever known. There was the greatest demand we had ever known for our goods and we began sending them across the ocean as fast as the ships would carry them. On top of that came higher wages, and larger purchasing power of domestic consumers. It was a matter of whether we could fill the orders. We were in the strongest sellers' market we had ever seen. Our purchasing agents became the salesmen and the salesmen took on the attitude of the former purchasing agents. It was a question of, When can you give it to us? Can you not give it to us a little quicker? It was a case of taking anything; it was the promoter's time, the promoter's delight; anything would go across; men thronged into business who could not have met the competition that existed prior to 1915. The numbers of people now in certain industries are double what they used to be. In addition there was a tremendous increase in our production facilities. Machine-tools were produced in large quantities, our shops were filled up with them and the floor-space was increased. On the farms we put new areas under cultivation; we expanded in agriculture just as fast as in manufacture.

Post-Armistice Business

The Armistice was signed. It should have been evident to all of us that conditions would change. We slowed up, we watched and waited, and we got a little different condition for 2 or 3 months. Then suddenly there was more business than we had before. In analyzing the situation we had forgotten that in filling the demands of Europe we had been holding back the filling of domestic orders. We took care of that home consumption, and economic principles began to act. We all planned for a big fall business in 1920. We pyramided our orders for raw material and parts. We were figuring that our shipments in September, October, November and December would be at least 50 per cent greater than they were in the fall before, which was a wonderful season, but those who could read saw signs as far back as May of little hitches here and there in the sales. Little quivers in the sales curve began in June and July.

Big Inventories Maintained

Did we take any heed? Did we start canceling orders for material? As a rule, no. A few of the wise ones did, but they were few and far between. Then when that wonderful business that was to come in the fall dropped down to an off-season volume, did those pyramided orders drop down? They surely did not; they piled up until our receiving-rooms were filled from floor to ceiling. What happened? We had inventories large enough to take care of twice the volume of business that we expected to get.

We went into January of last year with those big inventories. We had big stocks of goods out in the field in the dealers' hands. Our order records were fairly good in some instances, but an order was not a shipment, and while Mr. Distributor and Mr. Dealer and Mr. Salesman and Mr. Merchant were absorbing the excess stock that we had always carried as a floating reserve in the past, we were not making any shipments from the factory. When I say "we," I mean everybody.

The outlook was rather gloomy. What did we do about it? We got just as busy as we could to increase sales activity. Most of us were not in shape at that time to do anything with the prices. We had big fixed-charges to take care of. We had expanded; our properties were bigger; maybe we had some borrowed money. We cut our overhead expense and put our operations on

[1] Address delivered at the Chicago Service Dinner of the Society of Automotive Engineers, Inc., Feb. 1, 1922.

[2] General manager, Dayton Engineering Laboratories Co., Dayton, Ohio.

the safest and soundest basis possible, taking every means to decrease inventories. That entailed hardship and loss. It was one of the most difficult things that the managers of business in this Country ever had to do. But it was a sounder, saner thing than we did in the previous fall, when we hoped against hope that a tremendous volume of sales would come.

Requisite Conditions Today

Today the plant that cannot sell less product before it comes to the turning-point between profit and loss is in a very bad way. It should be able to make a profit on the sale of less goods than it could 1 year ago; otherwise it has not been properly liquidated. If it has not been properly liquidated, it certainly should make the dust fly to get into that condition.

Goods are beginning to come from Europe. At Christmas time we were flooded with German cutlery and small articles that do not require big tooling, the things that the Germans are expert in making; and more and more goods, regardless of any tariff that is put up, are bound to stream into this Couutry. Moreover, there is no great demand abroad for our manufactured products, and the exchange rates are such that it is most difficult to attempt to sell goods even in the countries that do have a demand for our goods. We who are in the manufacturing business must first stimulate home consumption and, if we have larger plants than the amount of business we can do justifies, perhaps we will have to close up a couple of buildings or shut off a portion of the factory, putting ourselves into such shape that with the amount of sales expectation we have we can go into black figures. Getting onto that kind of a basis is one of the biggest achievements in doing business today.

Basis of Optimism

Now as to that optimism business. We have been through a period of liquidation. It started in the basic materials, such as wool, leather, cotton and copper, before it hit the articles that we sell. It has been going on and on until in the case of a lot of our basic materials we are down practically to prewar prices. In connection with the consumption abroad of our products, one cause for great optimism exists; our shipments of basic raw materials to Europe have fallen off very little in quantity. Only 6 per cent less grain went to Europe in the first 9 months of 1921 than in the first 9 months of 1920. There was a falling off of values, to be sure. In other words, Europe still has an enormous purchasing power for those raw materials that she absolutely has to have. If prosperous conditions are to be restored in this Country, the farmer must resume buying goods. The farmer will come back to buying goods for the reason that Europe will take a great part of the surplus he produces. There is every indication that she will take just as much this year as she did last year. If Russia were shipping wheat to the rest of the world, we would have a different story to tell. Argentina cannot supply all the needs. We can compete with her. Our surplus farm products, except in the case of corn, will be well taken care of by the demands from Europe. That is a most encouraging sign.

If I thought that liquidation is to continue to the ultimate limit, I would say it would be 2 or 3 years before we could get into the same optimistic frame of mind that we can get into now if we understand the situation. In other words, if we had to wait until Mr. Retailer sells his goods on a proportional basis to Mr. Wholesaler, and until the wage-earner gets the same wages that he got before the war, we would be waiting for liquidation to be completed entirely, and would have a long, hard journey ahead of us. We cannot do that, it seems to me; a barrier is set up by the inability of the retailer, with his high rents and expenses, to get down to the wholesaler's level. In addition, wages cannot come down until the price of living comes down.

I think that within a few months we shall take the path of least resistance. Wholesale prices are showing an upward tendency. They started some weeks ago; they tumbled back again but will make another start. We will do business again in fair volume, not on a boom-time basis. Prices in certain lines that have not been liquidated will continue to come down. We were on the tenth story during the war. We have come down to about the fourth story. We will stay there for a while and do a fair volume of business for 15 or 16 months. Then we will have another slowing-up period and go down to the third story. Finally, one of these days, we will get down to the ground. That is what has happened in the past in similar situations. Liquidation has never run to the point where everybody was evened up before business was resumed. The best authorities agree on that. That is why I am optimistic for the coming year. We should, however, be safe and sane optimists. We should not expect that by some miracle or channel that we cannot reason out or in some mysterious manner all of a sudden a great volume of sales will enable us to indulge in the extravagances we have been indulging in.

Factory Team-Play

This is a time when the head of a company ought to be surrounded by at least four good business-men working hand-in-glove with him. In the past we have been too highly specialized in our four departments. My idea of running a business is that there should be a head, a financial man, a manufacturing man, an engineer and a salesman. I believe that in our past operations great extravagances have often been set up because we had four specialists all working to their own ends and disregarding the interests of the other fellows. We have come to a point where those four men should know something about the others' business. They should cooperate and do the best team-work that is in them.

There have been too many companies in which the treasurer was the only business-man and everybody else was getting all he could for his department, thinking he was serving the business in a glorified fashion, regardless of what he was doing to the profit and loss statement. We must not permit that in these times. We cannot afford to do so. We must see that every one of these men understands that the reason we are in business is, not to boost the sales department, not to make the engineering department the only well-organized department, not to have mahogany furniture, but to make money through selling a sound and good product that does good to humanity. In the past too few of us have felt that this was the prime purpose.

The Business Budget

To meet a reasonable volume of business, that may still be too small for an over-expanded plant, let us all cooperate as business men, lay out our budget, find out what sales we must have against that budget, and then get them. I believe that in these days every business should be budgeted. The comptroller of every company should have passed in to him a statement fifteen days before the month in which the money will be spent, showing just exactly what every department-head will spend. That should be gone over and no man should be permitted to

spend money until the budget items have been questioned, considered and approved by the comptroller. No man running a business, when a fellow comes up to him and says, "I think we need a new floor in here," should reply, "Yes, go on and put it in." How does he know that the treasurer has the money to put that floor in during that particular month? The budget should be planned, the man from the receiving department should indicate how much money is to come in, and the treasurer should go over the proposition and say, "All right, we can afford to do that and we cannot afford to do this." If they cannot do it this month, let them put it off until a month when they can. The four men specified, operating together, should live within the budget. If you are living within a budget, you can pretty well bank on it that at the end of the year you are coming out all right. There has been too much tendency to let the sales-manager steam ahead with a heavy advertising campaign involving expenses unrelated to anything else. Have we not sometimes had the chief engineer working on a model that might be good in 1926? What good will it do us in 1922? Is not the manufacturing man sometimes switching all his machinery around to get a better routing when he could save considerable money by leaving it as it was for the amount of business we happen to be doing? Can we not help each other tremendously by coordinating all of those things and welding them into one useful business policy that the treasurer finally says can be handled? That is a thing we ought to look into very carefully.

Selecting Sales Territory

I am inclined to believe that in the selling end of the business matters will be difficult. Sales were difficult in 1911 and the 2 following years, but we got a good volume. We were pretty keen as salesmen in those days; we were pretty hard; we were well exercised. We must admit we got out of practice during the war; things came too easy; and we are pretty much out of practice yet. Some men absolutely did not try to sell anything; they do not know now whether they can sell; they are just overcome and are lying on their franchise. Other men were of sterner stuff; they met the conditions and got results.

What should we be doing in the sales end of the business? First, the chief engineer ought to know something about the selling, as should the treasurer and the whole team working together. The management should analyze what must be done. A great mistake that all of us can make this year is trying to do impossible things in selling goods. I can take you to sections of the Country where, in the case of our particular business, if you spent $100,000 in sales overhead, you would come out at the end of the year with about as many lighting plants as two good-sized fellows could sell under normal conditions. The business is not in the woods in those particular territories. Why should we make the mistake of burning up a lot of money trying to do the impossible? There are thousands of communities where sales can be made. Let us pick them out and put the best one at the top and the next one below it and so forth, listing them according to the sales resistance. Let us not burn up big appropriations advertising to dead ones. Advertise to live ones. Work the spots that are good for all that is in them.

We are in the refrigerating business. The other day I found that we had all our efforts concentrated up where icicles were hanging off the windows, in Minneapolis. You can imagine going in to see a prospect who, while he is ruminating on whether he will buy, sees a large icicle hanging onto the window. I said, "Why in heaven's name have we not got those men down in Florida where it's hot?" What blunders we can make if we do not go at the thing analytically all the time! Let us know our territories and demand from those where the business is the ultimate. Put the money in there. See to it that we have the backbone to tell that distributor in that territory, "You get that business," and lead him on to get it. It can be done. It will save us a large amount of money somewhere else.

Manufacturing Economy

On the manufacturing end of the business every economy that can be effected should be put into force. I am not in sympathy this year with the idea of saving half a cent on some operation and getting a $20,000 machine to do it; or with the wonderful expert who specifies where an operation comes in proper sequence, if we have to upset our factory to follow his instructions. I am not in sympathy with changes that are merely for looks or for whimsical reasons advanced by a fellow who is not a business-man, and takes out one row of machines and substitutes another that is entirely different. I have had the experience, after being away from the factory for a couple of weeks, of going down some familiar aisle and seeing something changed. I said, "Where are those grinding machines?"

"Well, you see, on account of doing such and such we had to take those out and put these in."

"What for?"

"Well, on that operation we saved a quarter of a cent."

I said, "Yes, and it will take you 1,000,000 years to get it back again."

I do not want to indicate that we should not have breadth of view in our management, or that we should not look into the future and get our costs down as low as we can. But, instead of proceeding in a highly technical way because we want to show what a wonderful shop we have, let us act in a business way. Then probably we will not make the proposed changes in 1922 at all. Let us consider the suggestions, make up a 1923 book, and begin jotting down the things that we should be planning for 1923. In our particular case I have issued a note that there will be no more moving this year. We will not do any moving until 1923. We have been in business 5 years and we have moved and moved until moving is our second name. Consequently, we are going to stop moving and stay right where we are for 1922.

Business Sense Essential

The point I am trying to make in citing the rather extreme instance is that I want the head of that maintenance department to be a business-man. Heretofore he has been the champion mover of the world; and he has been a good mover. He takes pride in his ability to move the Herculean machines and swing them over poles. But what would he do to the profit and loss sheet this year? I issued the order I mentioned so that he would get the business slant. Rules are made to be broken, however. If that man should prove that he could put $50,000 onto the profit and loss sheet, an exception would be made. He has to prove his case. After he has learned that there is something in the world besides having the ability to move Eiffel Tower without breaking it into pieces, he will be worth much more to the business.

I am not in sympathy with these men writing in books that nobody ever looks into. You go through your place and see a fellow with a huge book with little curlicues all over it; 4 years ago some fellow originated that book.

He hasn't looked at it for 3 years. Let us get that all out.

We used to be guarded to death. We had 34 men, I think, protecting the property. You would have thought the place was made of chocolate and all the kids were going to come in and lick it up. Sweep? We used to sweep until we could see the grain right down through the boards. Let us not look at the floor so much. It is a good idea to paint the edges white so the men will not squirt tobacco juice into the corners, but let us stop being sweepers, guarders and movers. Let us get over onto the profit and loss sheet.

One fine way to do it is to get a budget that cannot be broken. But that budget should be developed by team-play and not by coercion. We do not want a factory full of sour people. Get the budget by cooperation. Once any man in any department has the viewpoint that the real sport in business is in making the business sound, you have no difficulty in getting him to play the game with you. It is when he thinks you do not appreciate what a wonderful engineer he is, or what a wonderful sales-manager he is, it is when he has the prima-donna attitude, that you cannot get him to cooperate. When it can be shown that a greater tenor is the fellow who can write in black instead of red, you do not have any difficulty in getting the cooperation you want.

The Engineer's Period

I think that the engineer can do much in this business situation. In fact, I think that it is the engineer's period, and that he can take the place of the promoter. As I have indicated, you could get away with murder in business; you could make a thing almost any shape and without any appeal and, because they could not get good stuff people would take bad stuff. That day is over. We must give them the values, at the right prices; we must sell things that really have intrinsic merit. We have to take the attitude that with our product we are buying the other fellow's money; he is not buying it; we are buying dollars from him with it.

I believe the engineer can help in the situation by going to the general manager of his company and saying, "I want to know more about this business. I think I can help you out if I get a real business understanding of the whole proposition. I would like to meet with the manufacturing man and find out what it is that I can do to help you most." I will guarantee that there are many brilliant chief engineers in this Country who have no particular business viewpoint so crystallized in their mind that it is right in front of them every minute. We need cooperation badly. If the man at the head of the engineering department has the right attitude, he will transmit it to every member of his force; he has many men under him who can help him arrive at what he wants to do.

See if this applies in your business. For 6 years we have been working to perfect lighting-plants. We have in mind a product far beyond what we are delivering to the public at the present time. What have we been doing all those 6 years? We have been making the product better, bringing out a new model from time to time. We have been projecting into the future something that has in it greater facilities for serving the public. Can we not take from the engineering department all of the knowledge accumulated and swing it into only those things that will help us in the year 1922? Analyzing our situation, we found that we could. We will call 1000 of our salesmen together in a convention and present to them something that they can sell and make money out of, and add to the machine-hours in our factory. The engineer can analyze his accumulated experience and should see what he can do with it to make his product better this year.

In addition, the engineer can help very materially by studying every known method of producing at the lowest possible cost just as good an article as has been produced. Moreover, he can assist by studying the engineering changes he wants to put into effect. There are two types of engineering change. There is the engineering change that should be adopted immediately because the service department has indicated a weakness in a particular feature. The weakness is constantly bobbing up and we are pouring money out in service as a result. The more quickly we can cure the trouble the better. The other type of change, which is made more frequently, is actuated by theoretical considerations with a view to improving the product. Let us put that over until 1923. In other words, look at the matter purely from the customer's standpoint. If he is being served properly with the product as it stands, leave it alone; if not, put the change into effect. Great economies can be had by leaving the product alone. It costs the factory considerable money to change over to suit a particular engineering modification, including the expense of shifting machinery. When you decide upon a change you do not perhaps take something else into consideration which, not being in the right relationship, involves another change. It is like small-pox; it breeds fast if you do not look out.

The engineer can help wonderfully by using the very best of business sense in handling those changes that come through. This applies not only this year; it always applies. The engineer should be in touch with the selling end of the business. Then he can do much more in designing articles that appeal to the public strongly than if he shuts himself up in an office and does not know what is going on. Getting out and seeing the product in use is the thing that counts. I believe that the engineering staff should be sent out to service the product, just as much as possible. No service-man can go out and ascertain the exact condition of things and come back and make a desk engineer understand what he is talking about. But if Mr. Engineer goes out and dirties his lily-white hands mussing around with the product, you can bank on it that the next time he designs a model it will be "right-side-up" and of such construction that you can take a screw out when you want to.

Improved Business in Prospect

I look forward to this year being a very much better one than last year. I think that wonderful work was done last year in "getting back to earth." The process will have to continue in certain lines, but in the main business will improve on a sound basis. Do not take that as the final thing; we shall slow up again, come down again, until we finally get to the point where all things will be lined-up in the proper proportion. Let us understand that situation; let us do our part in shaping our product so we can make a profit on less sales than we used to get, because all of us cannot get as many sales as we used to get, when there is not as much buying-power as there used to be. We must operate our plants on the basis of the amount of sales we can get. If we do not, there is only one answer: some of us will be eliminated in the shuffle. We want to "put it across," and the way to put it across is to line-up in team-play, every man a business-man; every man, though he is a specialist in his own line, seeing to it that his viewpoint and the thing that he does are in the direction of putting his company where it ought to be.

Developing a Method for Testing Brake-Linings

By S. von Ammon[1]

Annual Meeting Paper *Illustrated with* Charts and Photographs

As a result of the general policy of the Motor Transport Corps to standardize the materials used for automotive vehicles for Army Service, in cooperation with the Bureau of Standards, the Society of Automotive Engineers and the automotive industry, the Bureau of Standards has been engaged for some time in developing a standard method for testing brake-linings. While the work is not completed, much information has been gained. This paper reports the progress of the work.

The equipment developed and the methods used for both main and supplementary tests are described. Information is given regarding the coefficient of friction, as influenced by various factors. The endurance test, showing the comparative behavior of linings under conditions similar to those of severe service, is believed to be satisfactory as developed. Further work is necessary before recommending the conditions for the other test, intended to determine the relative endurance under ordinary or light service. In work done so far with a cooled drum and over a very wide range of power absorption and speed, difficulties arising from the accumulation in the lining of particles of steel cut from the drum have persisted. Supplementary tests covering the tendency of a lining to stick when brakes are left applied on a hot drum, and to ascertain the relative absorption of oil and water, are described. The influence of oil and water on the coefficient of friction is shown.

This paper is presented as an account of the progress and present status of the investigation of brake-lining materials with which the Bureau of Standards has been occupied for some time. In addition to its general interest, it is hoped that the information offered will be of assistance to those who are about to take up, or have recently begun, experimental work along similar lines, with apparatus identical with that developed at the Bureau of Standards.

The investigation of brake-lining materials by the Bureau of Standards was undertaken as a result of the general policy of the Motor Transport Corps to standardize the requirements for materials and supplies for automotive vehicles for Army service, as outlined by its representatives on several occasions before the Society, in cooperation with the Bureau of Standards, the Society of Automotive Engineers, and the automotive industry. Many tests of brake-lining materials had been made in the engineering laboratories of the Motor Transport Corps in 1917 and 1918. At that time, however, it was not possible to devote much study to the determination of the most satisfactory conditions for a laboratory test. The conditions under which manufacturers of brake-lining materials had tested their products and under which acceptance tests were made by car builders were so varied that results were not comparable, and had yielded but little information. This lack of definite information and a recognized method of test made it necessary to develop a standard test for determining the relative merits of brake-linings, which could be used as a basis for specifications. In December 1919 a Subdivision of the Truck Division of the Standards Committee of the Society of Automotive Engineers, consisting of A. K. Brumbaugh, of the Autocar Co., chairman; W. T. Norton, Jr., chief engineer of the Motor Transport Corps; Dr. H. C. Dickinson, of the Bureau of Standards; and Clarence Carson, consulting engineer of Johns-Manville, Inc., formulated a tentative program for developing a standard method for testing brake-linings and invited brake-lining manufacturers to have engineering representatives attend a conference at the Bureau of Standards on Dec. 18, 1919, to discuss the proposed program. The equipment designed jointly by the Motor Transport Corps and the Bureau of Standards, and built by the former, was completed so that preliminary tests could be begun in August 1920.

Various modifications were found necessary during the preliminary work and these, together with others tending to improve operation and convenience in handling, were made from time to time at the Bureau. In view of the progress made, the Bureau of Standards invited representatives of the Motor Transport Corps, the Society of Automotive Engineers, and brake-lining and automobile manufacturers to a conference at the City of Washington on May 17, 1921. At this conference a report of the work done at the Bureau was given. Tentative recommendations for various parts of the test were offered by the Bureau, subject to modification as a result of further work planned chiefly to overcome difficulties encountered in the endurance test with a cooled drum. After completion of the preliminary work at the Bureau early in 1921, several brake-lining manufacturers, constituting a Subdivision on Brake-Linings of the Parts and Fittings Division of the Society's Standards Committee, built equipment following the design developed at the Bureau.

Since the conference of May 17, 1921, the Bureau has furnished complete drawings to all brake-lining manufacturers and other interested parties and, so far as is known, about one-third have had such equipment built. This represents 8 or 10 equipments in addition to that at the Bureau. It is hoped that the carrying on of experimental work on the same lines at many points will assist in overcoming difficulties encountered, bring to light any possible defects in apparatus or methods and result in an early agreement on a wholly satisfactory method for the test.

The cooperation of those participating is acknowledged, the Motor Transport Corps furnished the original equipment and supplies and provided a large part of the funds required; Mr. Carson aided with suggestions at different times and, on behalf of Johns-Manville, Inc., delegated H. Copleston to the Bureau from October to December 1920 to assist in the carrying out of the preliminary tests made during this period. Liberal supplies of sample lin-

[1] Associate mechanical engineer, Bureau of Standards, City of Washington.

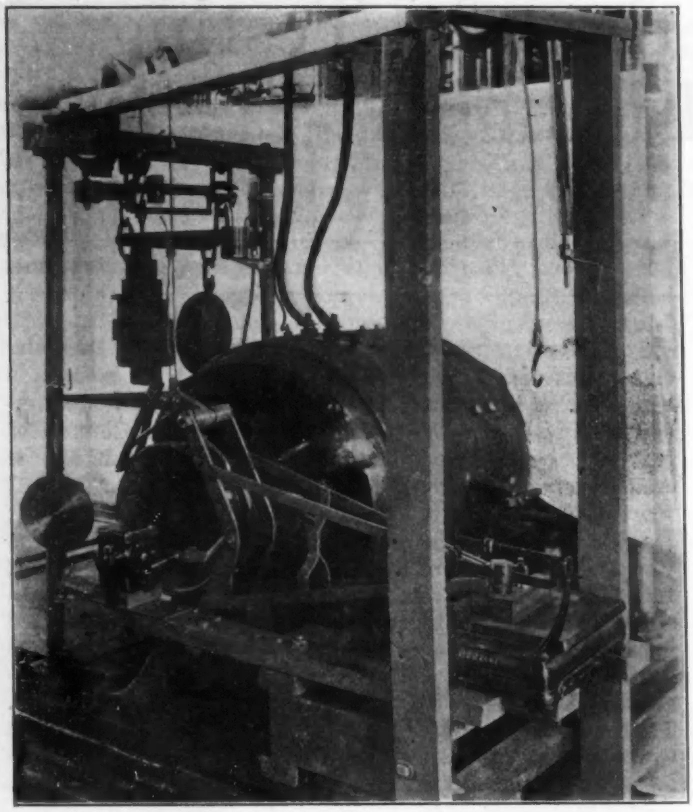


FIG. 1—TEST EQUIPMENT AS USED FOR TESTS WITH UNCOOLED DRUM

ings required for the tests, which necessitated frequent repeat tests, have been furnished to the Bureau from time to time by nearly all the manufacturers; these samples included many experimental ones not yet in regular production, the latter being of particular value in this work inasmuch as some at least represented probable future developments. The actual tests have been made by H. H. Allen, under my direction, in the automotive power-plants section of the Bureau of Standards.

GENERAL CONSIDERATIONS

The various features which it was thought required investigation are shown in the following abbreviated form of the orginal program, including some slight modifications and additions resulting from the discussion at the conference of Dec. 18, 1919. Its main divisions are considered as (*a*), fundamental, and (*b*), supplementary. Under (*a*) the coefficient of friction is investigated in relation to

(1) Dry lining
(2) Influence of water, oil, temperature and wear
(3) Constancy of the coefficient

Durability also is studied under (*a*), it having been decided to adopt the following:

(1) A standard rate of energy input, with consideration of established practice and limited to engine power
(2) A drum of standard material and surface, and 12 to 16 in. in diameter, at a speed of about 1200 r.p.m.
(3) Stock sizes of linings; preferably, the actual size considered
(4) A policy of wearing linings down to about one-half of their original thickness
(5) A long-time endurance test with the temperature kept constant by cooling water
(6) A severe-service test, the temperature of the drum being allowed to rise to equilibrium with constant power-absorption

The supplementary division includes

(1) Rivet-holding ability
(2) Sticking after cooling on a hot drum of both new and worn linings
(3) Change of thickness due to the absorption of water and oil

The general considerations are inclusive of the

(1) Use of flexible-band shoes for supporting linings
(2) Adoption of a standard method of riveting samples to shoes
(3) The determination of the proportion and quality of asbestos and other materials used is not considered necessary, nor is a test for volatile matter thought important

It has been the aim throughout to develop simple equipment and methods that would not entail a large expenditure for apparatus or require exceptional skill or judgment to obtain results of sufficient accuracy. In view of the nature of the materials dealt with and the many factors influencing the results, it is satisfactory if the test results are accurate within 5 per cent. The methods used permit a much greater accuracy than this.

The conditions of a laboratory test of this kind should approximate as nearly as possible those existing in actual service. It is desirable, however, to accelerate the testing of a sample and, for this purpose, it is permissible to depart from actual service conditions so long as the test results continue to indicate fairly the relative ability of the materials tested, under service conditions. This applies to both the coefficient of friction and the comparative endurance of various linings. At different times during the investigation it was found that conditions appearing suitable with some linings proved less so with others, and this made additional work necessary.

In establishing the conditions for the tests, sufficient latitude should be allowed for new and improved materials likely to be developed in the near future. No conditions should be included as a part of either tests or specifications that might place unnecessary restraint on the choice of materials or methods of manufacture, other than the ability of the finished product to render the service required. At present, information available regarding the composition of linings and its influence on their behavior in operation is too scant to base specifications on more than service tests made either in the laboratory or on the road. Systematic investigations of the materials and treatments used will be made, however, and may show their influence on the results in service. When the knowledge in this connection is sufficient, limitations covering the composition can be included in specifications.

EQUIPMENT

Figs. 1 to 3 show the equipment used. A standard brake-drum 14 in. in diameter and 2½ in. wide, a size in extensive use and therefore readily obtainable on the market, is mounted on the end of a shaft that can be driven by any conveniently available power as shown in Figs. 1 and 2. The sample linings bearing on the outside of the drum are riveted to two flexible steel shoes which in turn are mounted in a framework, as shown in Fig. 3. The position of the upper arm *a* is fixed, while the lower arm *b* is movable about the joint *c*. An adjustable tension-rod *d* and spring-balance *e* placed between the free ends of the pressure-arms serve to regulate and measure the pressure with which the shoes are

pressed against the drum. An extension of the frame f forms a torque-arm and rests on platform scales for measuring the torque. The whole frame is suspended from above over small pulleys, and its weight is counterbalanced to equalize the pressure on the upper and lower shoes. The drums are of low-carbon steel, the material most generally used at present. Each lining sample is secured to its steel shoes by eight brass tubular rivets, with a definite spacing adopted as standard, the rivet-holes in the lining being drilled carefully and countersunk to a fixed depth of about one-half the lining thickness. The samples are 2 in. wide, ¼ in. thick and 11 in. long, each covering 90 deg. of the drum. The total area in contact, after deducting the area of the rivet-holes, is 42.75 sq. in.

From the dimensions shown in Fig. 3 it will be found that

$$hp. = 0.000444\ W\,S \quad (1)$$
$$Q = 10\,P \quad (2)$$
$$U = Q \div 42.75 \quad (3)$$
$$f = F \div Q$$
$$= LW \div RQ$$
$$= 4W \div Q \quad (4)$$

where

$hp.$ = horsepower
W = force acting at the end of the torque-arm, in pounds
S = speed, in revolutions per minute
Q = total pressure on the linings, in pounds per square inch
P = force between the tension-arms, in pounds, as indicated on the spring-balance
U = unit-pressure on the linings in pounds per square inch
f = coefficient of friction
F = force at the circumference of the drum, in pounds
L = length of the torque-arm, 28 in.
R = drum radius, 7 in.

The wear is checked by measuring the change in distance C between the prick-punch marks just below the knife-edge seats at the ends of the two tension-arms; then, $(C_1 - C_2) \div 10$ = the average thickness loss in inches of one lining sample. To dampen the movement of the weighing-beam of the platform-scale, a small dash-pot is connected with the end of the arm. This is not shown in the photograph, because it is unnecessary when the torque is measured by an electric dynamometer. One end of the upper shoe is kept in a fixed position relative to the frame by the braces g, to prevent sidewise travel of the whole frame when in operation. Fig. 1 shows the open, uncooled drum, mounted; and Fig. 2 shows the covered drum for water-cooling.

Coefficient of Friction

The coefficient of friction of fabric brake-linings is influenced by many factors. Among these are the unit pressure, the surface speed, the temperature and the condition of the wearing surfaces. The last differs not only as a result of the varying methods of manufacture, but changes constantly as wear progresses. It was found that the changes in the coefficient of friction that the preliminary tests showed as resulting from varying speed and pressure at constant drum-temperature are comparatively small, and that other considerations that are referred to later are more important in limiting the choice of speed and power-absorption for a practical test.

Comparing the values of the coefficient of friction as obtained during extended runs with the speed or the horsepower constant and the other variable changed, the average and the maximum values of the coefficient reached during various parts of such a run show no consistent variation. It is not only very difficult to establish any definite relation between these values but, in view of the great difference in linings, the infinite number of possible combinations of service conditions and the many factors influencing the coefficient, the establishing of such relations proves of comparatively little value. It appears that the aim of manufacture should be to produce material that will have a reasonably constant coefficient of friction; that the coefficient, under the most unfavorable conditions and even for very short periods, should not go below a certain minimum value; and that, in addition, the material should show the longest possible life. The minimum values of the coefficient of friction, from 0.11 to 0.25, obtain during severe service and

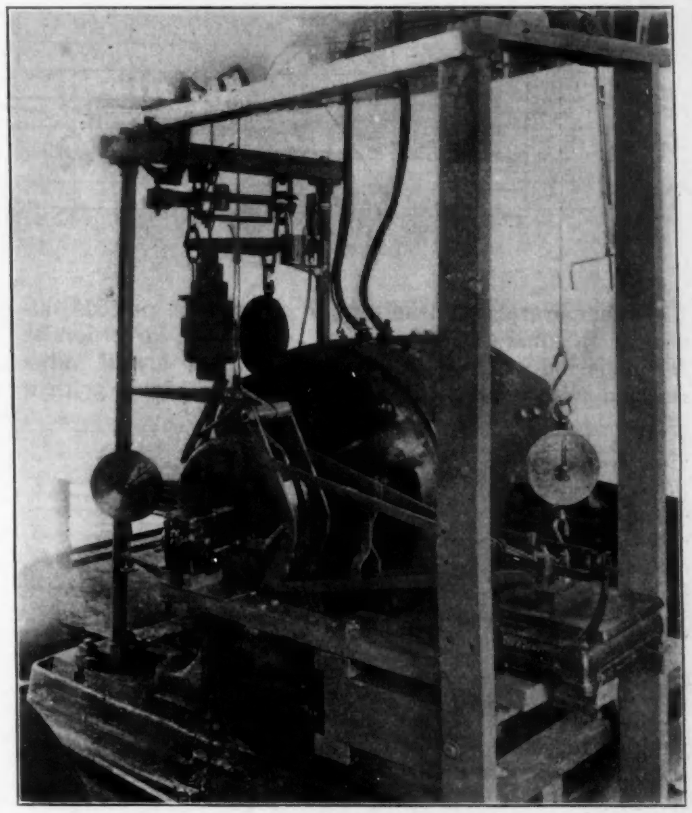


Fig. 2—Test Equipment as Used for Tests with Cooled Drum and Oscillator

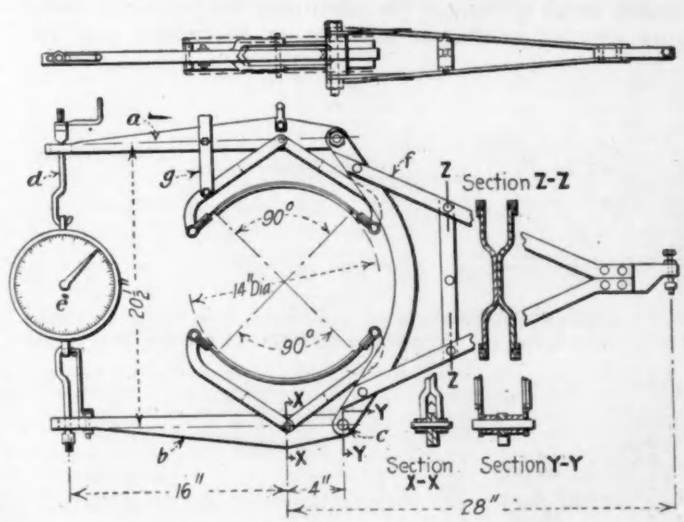


Fig. 3—Assembly Drawing of Brake-Lining Test Mechanism

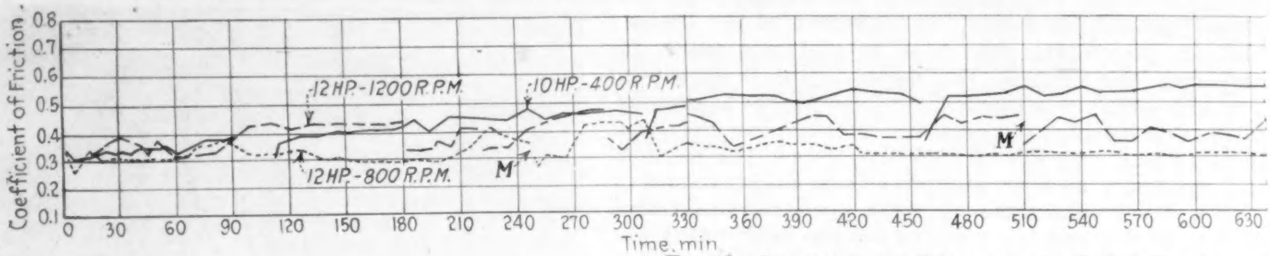


FIG. 10—COEFFICIENT OF FRICTION WITH COOLED DRUM WITH

high temperatures; usually, for only short periods, although in some cases they have been observed to persist for a period of from 15 to 60 min. The lowest value reached with a given lining frequently is higher with a

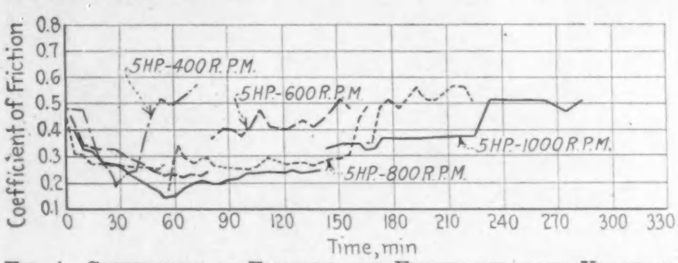


FIG. 4—COEFFICIENT OF FRICTION AND ENDURANCE WITH UNCOOLED DRUM AT 5 HP. AND 400, 600, 800 AND 1000 R.P.M.

combination of speed and horsepower that is not the most severe as regards the endurance of the particular lining.

The lowest values result from the action of the heat

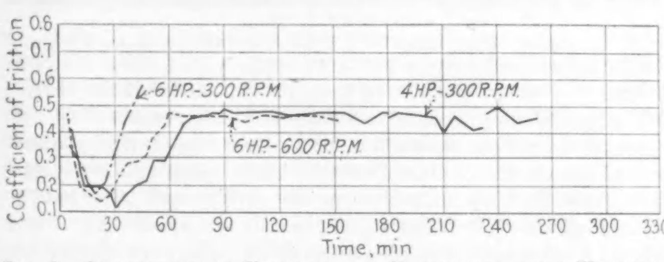


FIG. 5—COEFFICIENT OF FRICTION AND ENDURANCE WITH UNCOOLED DRUM WITH 4 HP. AT 300 R.P.M. AND 6 HP. AT 300 AND 600 R.P.M.

on the impregnating compounds during the severe-service runs, as is seen from the character of the curves in Figs. 4 to 7. When this change has taken place, the coefficient rises again and remains high during the remainder of the run. It seems necessary therefore to design brakes so as to reduce the maximum temperature occurring insofar as that is possible, or to employ only im-

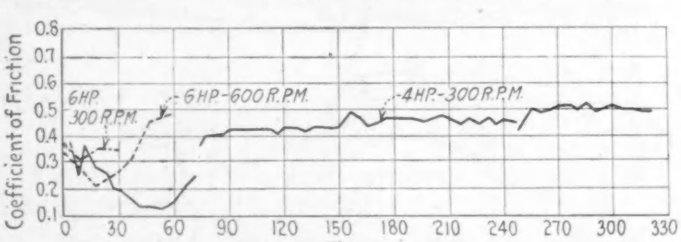


FIG. 6—COEFFICIENT OF FRICTION AND ENDURANCE WITH UNCOOLED DRUM WITH 4 HP. AT 300 R.P.M. AND 6 HP. AT 300 AND 600 R.P.M.

pregnating compounds having high heat-resistance, to reduce the drop in the coefficient that results from high operating-temperatures. This effect is seen by comparing the curves relating to the tests made with an uncooled drum and those made with a cooled drum.

Compounds having a high heat-resistance also lengthen the life of the lining insofar as their capacity for bind-

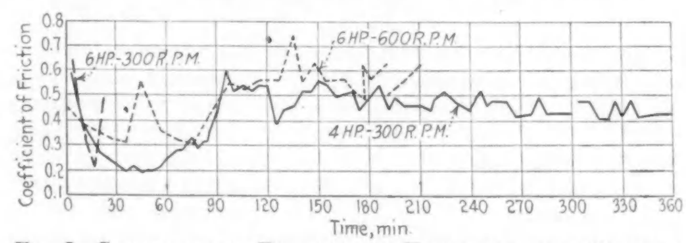


FIG. 7—COEFFICIENT OF FRICTION AND ENDURANCE WITH UNCOOLED DRUM WITH 4 HP. AT 300 R.P.M. AND 6 HP. AT 300 AND 600 R.P.M.

ing the asbestos fibers together is maintained better throughout the life of the lining. This is indicated by the results, which show that the linings with the longest life maintain their minimum coefficient over shorter periods than linings with a shorter life.

In view of the wide variations in the coefficient of friction and the low values reached at times, it is neces-

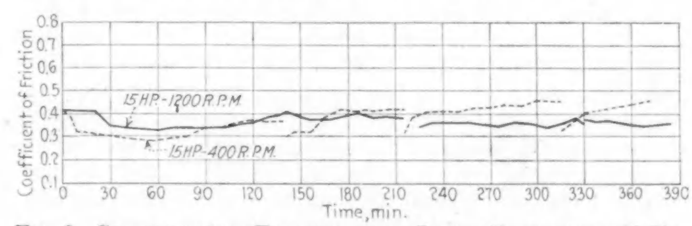


FIG. 8—COEFFICIENT OF FRICTION WITH COOLED DRUM WITH 15 HP. AT 400 AND 1200 R.P.M.

sary, of course, to base the design of brakes on a reasonably low value of the coefficient. In addition, allowance must be made for the application of a pedal pressure considerably higher than normal during the periods when the coefficient is reduced to its minimum value as a result of continued severe application and the consequent heating, particularly as the minimum value may occur when braking power is most needed. Comparing the coefficients found during the runs with cooled and uncooled drums, it is found that, with the cooled drum

(1) The rapid drop, characteristic of the early part of the run with an uncooled drum, is absent
(2) The changes with the cooled drum are not so rapid, nor as large

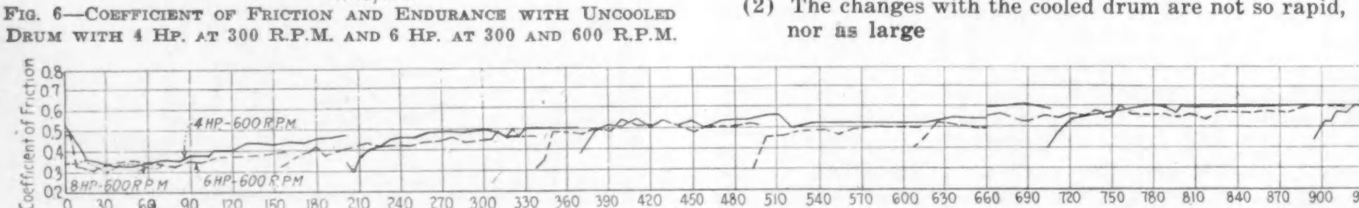
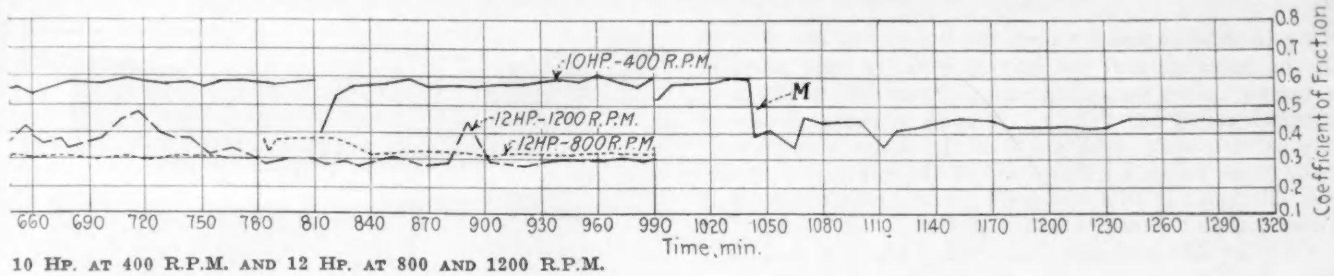


FIG. 11—COEFFICIENT OF FRICTION WITH COOLED



10 Hp. at 400 R.P.M. and 12 Hp. at 800 and 1200 R.P.M.

(3) The minimum values do not reach the low levels resulting from the high temperatures in the severe-service run

Figs. 8 to 12 show the range of variation in the coefficient over a wide range of speed and horsepower on a cooled drum. The coefficient of friction is plotted against time. The several curves in each figure were obtained by making tests on different samples of the same lining. Fig. 12 applies to the same lining as that in Fig. 11, but gives the results with much increased unit-pressures. The samples in this case had only 37 per cent of the normal area and consisted of pieces $1\frac{3}{8}$ in. long; three were riveted to each shoe, one in the center and one at each end. The unit-pressures in this case ranged from 28 to 42 lb. per sq. in. All of these results, as well as those obtained with speeds of from 400 to 1200 r.p.m. and a power input of from 25 to 40 hp., indicate that we need not be limited by the variations occurring in the coefficient of friction in the selection of a suitable combination of speed and horsepower for the test with cooled drum; the limitations to be observed result from other considerations, which are stated later herein.

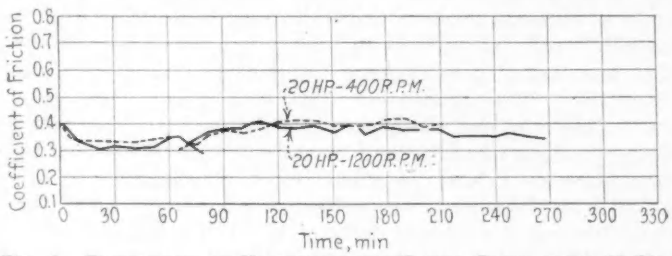


Fig. 9—Coefficient of Friction with Cooled Drum with 20 Hp. at 400 and 1200 R.P.M.

A number of similar comparisons relating to tests with an uncooled drum are shown in Figs. 4 to 7 and Fig. 13; here we find again that the variations in the coefficient of friction are not the important factor in determining the most suitable combination of speed and horsepower for these tests. Table 1 shows the maximum, minimum and average values of the coefficient of friction, determined from all the tests that were made.

TABLE 1—RANGE OF THE COEFFICIENT OF FRICTION

	Cooled Drum	Uncooled Drum
Maximum	0.75	0.75
Minimum	0.25	0.11
High Average Value for Run	0.60	0.60
Low Average Value for Run	0.33	0.32
Majority of Averages between	0.35 and 0.45	0.45 and 0.50

Periodic fluctuations in the coefficient are more marked in some linings than in others; certain combinations of speed and horsepower may tend to increase these fluctuations in a given lining. The more pronounced the tendency to such fluctuations is, the greater the tendency to seize, squeak and chatter will be.

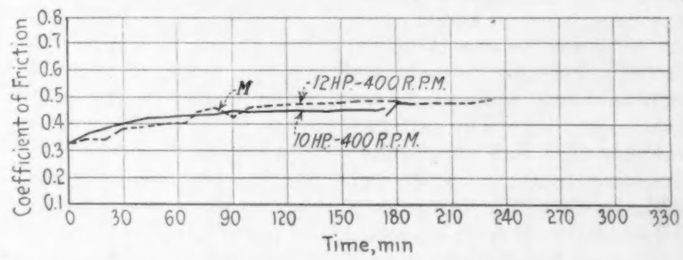


Fig. 12—Test with High Unit-Pressures with Cooled Drum with 10 and 12 Hp. at 400 R.P.M.

Comparisons that have been made between linings of the woven and the folded and rubberized types do not indicate that maximum, minimum or average values vary markedly as a result of these two methods of construction. The wide range over which the coefficient of a given lining varies and, particularly, the low values to which the coefficient in practically all linings drops during the early part of the severe-service test, are points of special interest. These low values are, in most cases, much below the average values obtained later during the severe-service run, and are also below the average of the endurance test with a cooled drum. Although appearing only during the early part of the tests, they may occur in service at any time and may continue for long periods, depending entirely upon the use made of the brake from time to time and are therefore the more undesirable.

During the preliminary tests with the cooled drum, a number of temperature measurements were made by in-

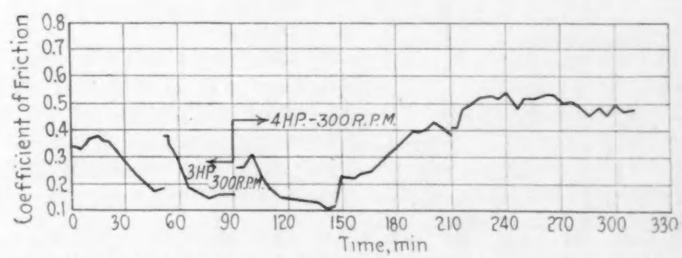
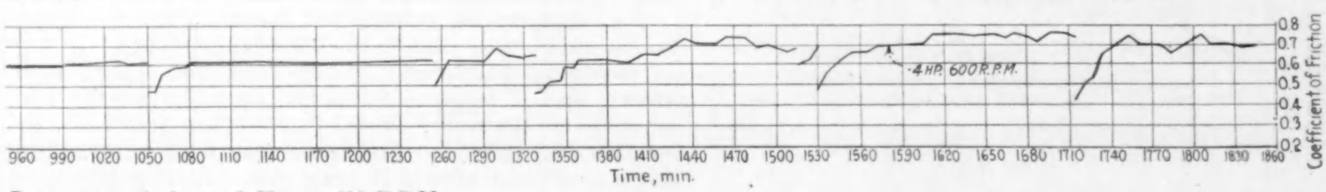


Fig. 13—Coefficient of Friction with Uncooled Drum with 3 Hp. at 300 R.P.M. Followed by 4 Hp. at the Same Speed



Drum with 4, 6 and 8 Hp. at 600 R.P.M.

serting thermocouples between the lining and the shoe at both the entering and the leaving ends of each sample. The temperatures measured ranged from 150 to 200 deg. cent. (302 to 392 deg. fahr.). In some of the preliminary severe-service tests some parts of the drum became red-hot for short periods. However, at the speed and horse-power adopted for this test with an uncooled drum, it is estimated that the temperature at the face of the lining lies between 250 and 450 deg. cent. (482 and 842 deg. fahr.).

Influence of Oil and Water on the Coefficient

The influence of oil and water on the coefficient of friction is shown in the curves in Fig. 14. The samples used were standard samples that had been worn-down in previous tests to about one-half their original thickness. As noted on the charts, the first two groups had been subjected previously to tests with a cooled drum, so that the impregnating compounds were substantially in the original condition. The last two curves were obtained with samples that had undergone severe-service tests with an uncooled drum; here the impregnation had been carbonized, leaving the lining in a more absorbent condition. All of the tests with oil and water were made on a cooled drum and the linings were first run dry until the coefficient of friction had become steady.

The lining to which the first curve refers, sample No. 30 (A-1), was then submerged in oil at 100 deg. cent. (212 deg. fahr.) for 1 hr., the test was resumed and, during the period marked in the plot, oil was swabbed on the drum. The two curves in the second chart refer to a folded and to a woven lining. During the period shown water was sprayed on the periphery of the drum at two opposite points between the shoes. In the case of the last two charts, water was applied for the periods shown

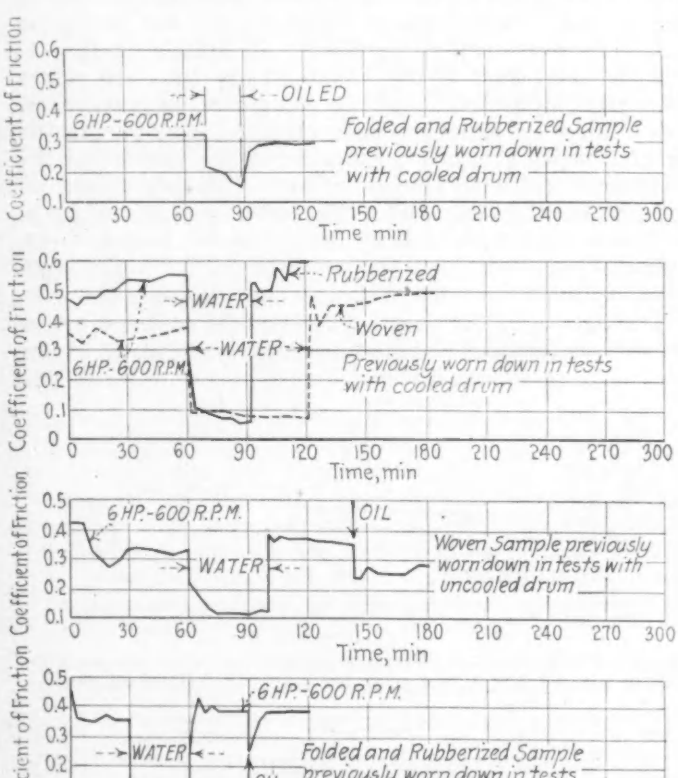


Fig. 14—Influence of Oil and Water upon the Coefficient of Friction

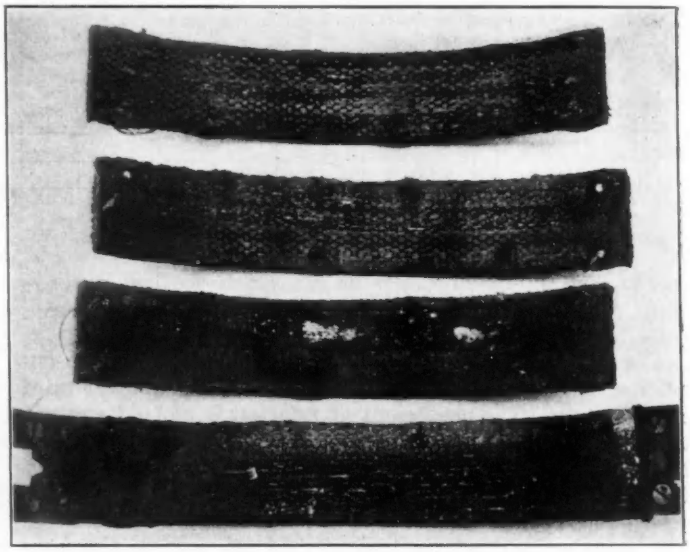


Fig. 15—Samples Showing Steel Particles Embedded in the Lining after a Test with the Cooled Drum

and as already described. After continuing the run for a time without water, these linings were thoroughly soaked in oil; the oil was not heated in this case, as the absorbent condition of these two linings made this unnecessary. The drum was also well-oiled. The very marked drop in the coefficient of friction resulting from the application of oil as well as water, is clearly shown in these curves. It will be noted also that when the application is discontinued the coefficient rises very rapidly to approximately its former value. In the third chart, sample No. 53 (A-15), the low value of the coefficient continues for some time as a result of the absorbent condition of the lining.

The fact that water is expelled and evaporated more rapidly than oil is shown by the quicker rise in the coefficient as shown in the curves, in comparison with the rise when oiling is discontinued. Nevertheless, it is important that the changes in the coefficient of friction resulting from the presence of surface water or moisture absorbed by the lining should be small. With a well-designed axle the amount of oil reaching the brakes should be very limited and, as this oil is confined usually to only a part of the braking surface, the effect of oil as shown by the curves can be considered as being extreme, and to be expected only where undue oil-leakage takes place.

Endurance Tests With a Cooled Drum

From the first, it has been considered advisable to make two distinct tests for durability to establish the behavior of a lining under the varying conditions to which it may be subjected in service. The user would thus be able to select linings in accordance with the average service for which they are intended. These conditions differ not only with wheel and propeller-shaft or transmission brakes, but with the design of the vehicle and the general topography of the locality in which the car is used.

Fig. 2 shows the covered and water-cooled drum used in the tests with controlled drum-temperature. A flow of water is maintained by the feed and siphon pipes shown, and it is regulated so as to maintain the temperature of the water close to the boiling-point. To accelerate the tests, the first work was done with a high drum-speed and high unit-pressures. Short preliminary runs indicated that, with a speed of 1200 r.p.m., 30 hp.

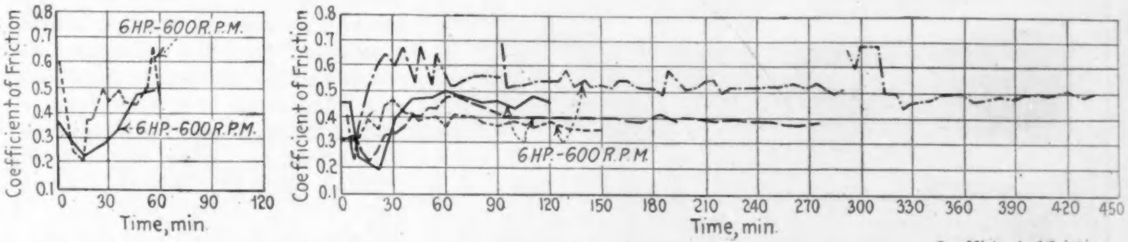


FIG. 16—COEFFICIENT OF FRICTION AND ENDURANCE TEST OF LININGS OF SMALL (AT THE LEFT) AND MEDIUM (AT THE RIGHT) ENDURANCE

or even more might be absorbed. However, more extended tests showed that, under these conditions, the linings cut the drum and the steel removed imbedded itself in the lining and grooved the drum severely. This condition was not improved materially in successive tests with power reduced to 10 hp. and speeds between 1200 and 600 r.p.m. An oscillating device was, therefore, connected with the frame of the apparatus. This device consists of a small worm-gear driven from the dynamometer and connected with the frame so as to move it back-and-forth about 1/4 in. over the face of the brake-drum once in every 52 revolutions of the drum, as shown in Fig. 2. By this means the scoring was reduced and the grooving of the drum prevented by distributing the cutting action over a greater portion of the face.

Many tests were made in regard to power absorption, resulting in unit pressures of 96 down to between 2 and 3 lb. per sq. in., which is equivalent to from 40 to 4 hp., and speeds from 1200 to 400 r.p.m., using representative samples of the woven, folded and molded types. In all cases, however, cutting and imbedding of the metal in the lining was found. The fine particles first lodging in the lining increased the cutting action and caused additional steel to gather and, probably due to local heating, the accumulated metal was fused together until, in very severe cases, irregular pieces were found, some of which had an area of about 1 sq. in. and a thickness of from 1/32 to 1/16 in. The tests with samples of reduced area, referred to previously, formed part of this series. It was thought that, with such short samples, there might be less tendency of the steel to accumulate in the linings, but this was not found to be the case.

The point at which this cutting occurred varied according to the power absorption and speed. The tests indicate that it generally begins soon after the face of the lining is worn down to a smooth surface, when the wires are first exposed. Fig. 15 shows selected samples with imbedded steel. The beginning of the cutting usually can be noticed clearly on the drum by the appearance of a narrow band, and slight fluctuations in the coefficient result. When the metal begins to accumulate in the lining, there is a decrease in the coefficient which is marked at times, as is shown in Fig. 10 at the 1050-min. point.

It will be seen that these circumstances make it very

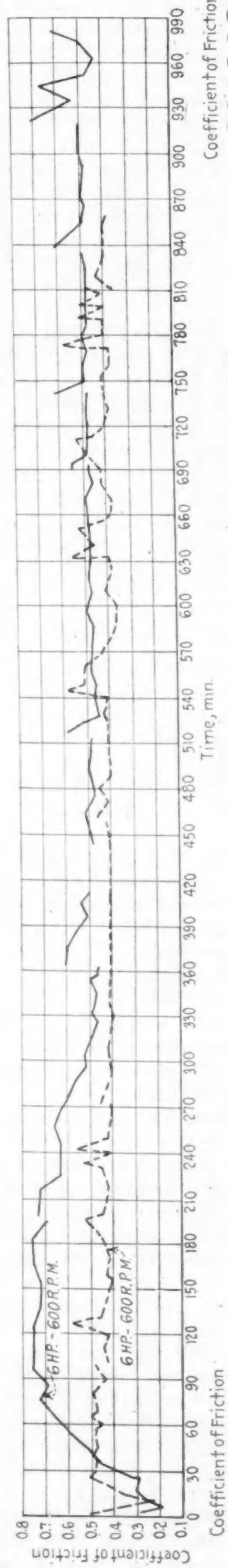
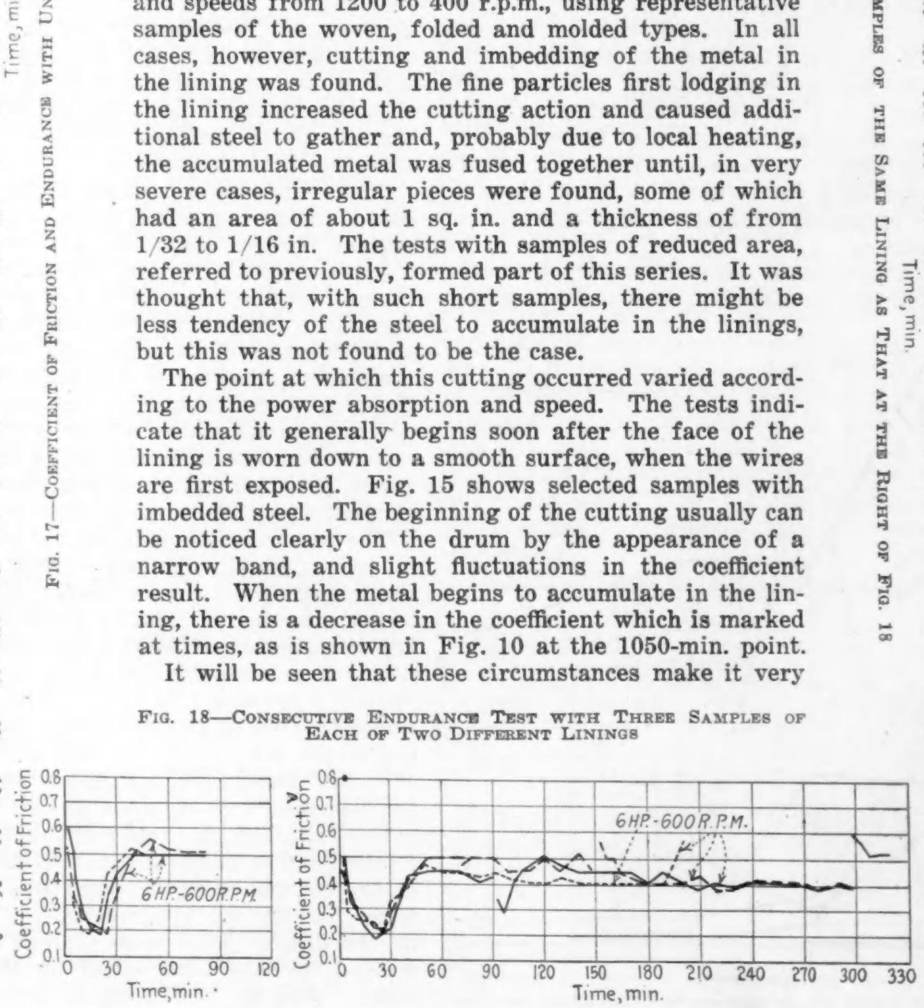


FIG. 17—COEFFICIENT OF FRICTION AND ENDURANCE WITH UNCOOLED DRUM AT 6 HP. AND 600 R.P.M.

FIG. 18—CONSECUTIVE ENDURANCE TEST WITH THREE SAMPLES OF EACH OF TWO DIFFERENT LININGS



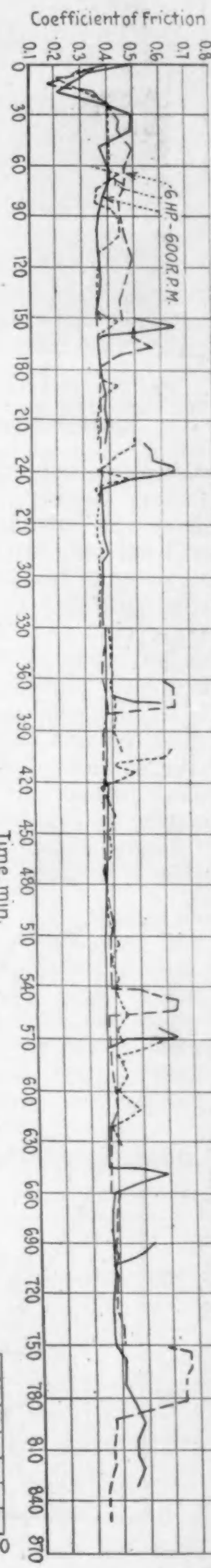


FIG. 19—ENDURANCE TEST WITH THREE SAMPLES OF THE SAME LINING AS THAT AT THE RIGHT OF FIG. 18

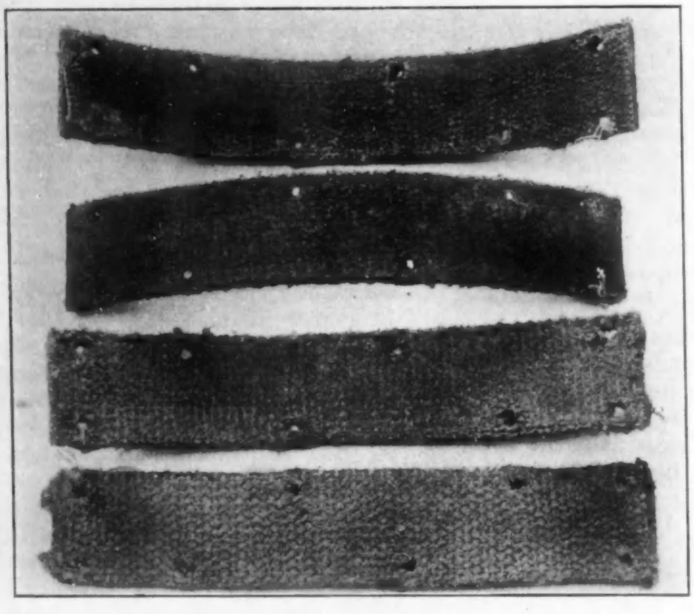


FIG. 20—APPEARANCE OF LININGS AFTER SEVERE SERVICE TEST
The Upper Pair Are Two Views of a Typical Folded and Rubberized Lining, While Below Is Shown a Typical Woven Lining

difficult to determine conditions for this test in a satisfactory manner. If conditions are adopted that tend to delay the cutting action, the time required for a test will not only be inconveniently long, but the wear will be so small that it will be difficult to determine the relative durability fairly; and no data will be obtained covering either the coefficient of friction or the durability of the center of the lining. Some linings probably have a greater tendency to cut the drum than others; if this is so, it would be desirable, of course, to have the test show this and thus lead to improved construction. However, in view of the many variables which enter, there is small prospect of obtaining accurate and reliable information on this feature.

Accumulation of metal does not occur during the tests with an uncooled drum, presumably because the holding power of the impregnating compounds has been destroyed by the high temperatures, and steel particles are carried off with the asbestos as wear proceeds. The use of the oscillating device constitutes a departure from service conditions and, therefore, it is of interest to note that with a number of samples tested, both with and without an oscillator, the differences in the coefficient of friction were negligible. During the continuance of the tests with a cooled drum, there is no apparent change in the nature of the impregnating compounds. In brake-linings worn-down in actual service, particles of steel are found only occasionally, but the continuous application of the lining to the drum during the test appears to result in a greater tendency to collect the metal particles in the lining.

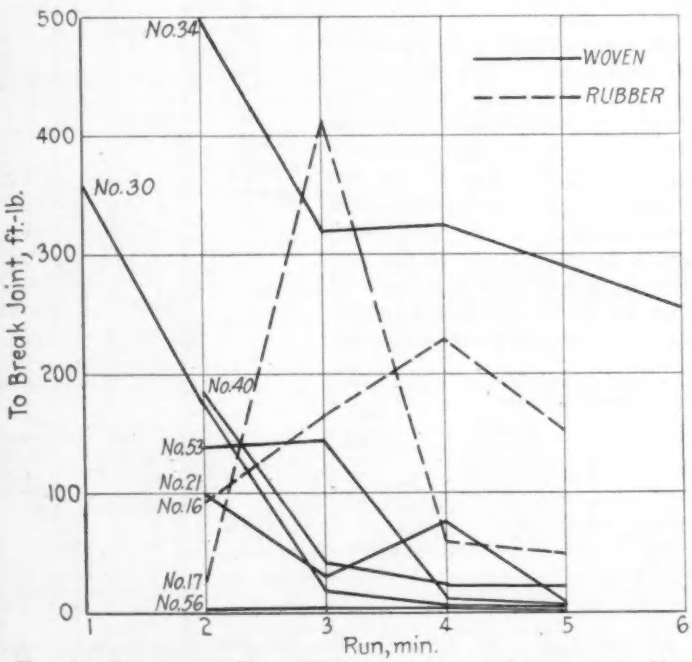


FIG. 21—RESULTS OF TESTS TO ASCERTAIN THE TENDENCY OF HOT LINING TO STICK TO THE DRUM

Typical results of these tests are shown in Fig. 4 and in Figs. 9 to 12, in some of which the points at which metal imbedded in the linings was first found are marked by the letter *M*. In all the curves a break denotes an interruption of the run. The interruptions occurred regularly at the end of working hours and were due occasionally to cessation of the power supply. Since the adoption of the speed of 600 r.p.m. for the severe-service test with an uncooled drum, this speed has been adhered to in the more recent tests with a cooled drum, on account of the obvious advantages of using the same speed in both cases.

SEVERE-SERVICE TEST WITH UNCOOLED DRUM

To determine the best conditions for the severe-service test with an uncooled drum as regards speed and power absorption, a considerable number of trials were made with speeds of 300, 400, 600, 800 and 1000 r.p.m., and with power inputs of 4, 5, 6, 7½ and 10 hp. It was found that there was no need for, or advantage gained from, the use of the oscillating device in this test and it has therefore not been used.

The higher power-values at all of the above stated speeds led to very rapid destruction of the samples, and neither the coefficient of friction nor the relative endurance could be established satisfactorily. The combination of 6 hp. and 600 r.p.m. proved to be most satisfactory; it limited the test to a reasonable length of time and brought out the maximum and minimum values of the coefficient of friction found with an uncooled drum. Samples of all available linings were tested at this speed and horsepower and in a number of cases several repeat tests were made with samples of the same lining. As a result, the combination of 6 hp. and 600 r.p.m. has been adopted as satisfactory for this test.

The test is continued until the samples are worn-down to approximately one-half of their original thickness; the length of the curves cannot, however, be taken as a direct measure of relative durability without considering the amount of wear. The majority of the linings required a test-period of from 3 to 7 hr. Only a few showed a running time of less than 1 hr., and these were understood to be experimental types, while the greatest endurance was shown by one lining that was run for 16½ hr. Soon after the load is applied in this test, the impregnating materials soften and burn-out to a varying extent, causing the rapid changes in the coefficient of friction shown in the curves. The condition of the drum at the conclusion of the runs was always good. Sometimes, during the progress of a run, a coating formed on the drum. With some linings this was smooth and seemed to have little effect on the linings. In other cases, however, the coating formed was rough and hastened the destruction of the lining. Figs. 4 to 7 and

Fig. 13 are referred to again, and further results of the severe-service tests are shown in Figs. 16 to 19. At the conclusion of this test, the folded and rubberized linings have usually been found to retain greater stiffness, as shown in Fig. 20.

Determination of Relative Durability

For both the severe-service runs and the tests with a cooled drum, the reduction in both the thickness and the weight was determined. While this information is recorded at the Bureau for reference, it is believed that the user is interested primarily in the thickness loss rather than the weight loss; therefore, it seems preferable to use a wear factor for judging the relative endurance of various linings that shows the relation between the thickness loss and the time, and to disregard the weight loss. Manufacturers may, however, find it useful to record the weight loss as well. The reduction in the thickness is not uniform during the progress of the test, particularly in the severe-service test and, for this reason, measurements are taken at the Bureau during each stop. This is done by measuring the distance between the punch-marks on the pressure-arms by a trammel. To reduce the influence on the wear measurements of uneven contact with the shoe and to some extent also the initial compressibility of the lining, it has been found advisable before beginning the test to raise the tension on the pressure-arms to 150 lb. as shown by the spring-balance. Before each measurement is taken, the tension on the pressure-arms is released and then brought to 50 lb.

In linings of both small and great endurance, the rate of wear may be found to increase or decrease as the test progresses; where the bonding quality of the impregnating compound has been destroyed and a short-stapled fiber has been used, or a rough coating has formed on the drum, the rate of wear during the last part of the run may become very high. These factors necessitate a number of precautions so that fair relative-wear factors can be obtained for different linings, and they contribute also to differences in the results of consecutive tests with several samples of the same lining. In routine tests made by the Bureau three consecutive severe-service tests are being made of each lining to obtain information on the constancy of results, as well as average wear factors. Dividing the thickness loss of one lining sample in inches by the time in minutes gives inconvenient figures and, to avoid this, the decimal point is moved and the following method is adopted:

$$WF = [(C_1 - C_2) \div 10\,T] \cdot 10^6 \qquad (5)$$

where

$(C_1 - C_2) \div 10 =$ thickness loss of one lining as shown earlier

$T =$ total time in minutes

$WF =$ wear factor

Hence

$$WF = [(C_1 - C_2) \div T] \cdot 10^5 \qquad (6)$$

Wear factors for the severe-service test with the samples tested varied from 120 to 2680 for linings understood to be commercial products. Among experimental samples, one was found giving a better wear factor of 82, while a number of others were less favorable and showed wear factors up to 4840. Figs. 16 and 17 show a number of results obtained with representative samples in the severe-service test. Fig. 16 shows several with small endurance, and a group of four with medium endurance; this latter group shows the range in which the majority of commercial linings are found. Fig. 17 shows the results on two linings that were found to have exceptional endurance in the tests. It is interesting to note that, of the samples so far tested at the Bureau, linings of both the woven and the folded and rubberized types were found among those with the smallest and the greatest endurance, although it is understood that the compounds used in the two types are of distinctly different natures. In Figs. 18 and 19, the results of three consecutive tests on each of three different linings are shown. Some variation must be expected from both variability in the lining due to material and workmanship, and factors occurring during the test itself.

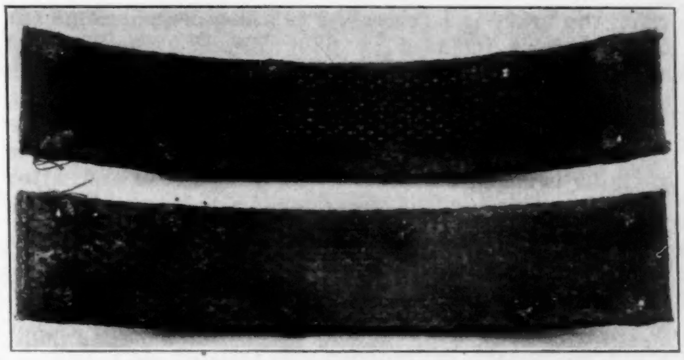


Fig. 22—Two Samples of Lining After the Sticking Test

Rivet-Holding Ability

No separate tests were carried out to ascertain the rivet-holding ability of the linings. In any such test the conditions should be similar to those in service. In addition to being riveted to the shoe, the lining should be under pressure between the drum and shoe as in service, and the force used to test the rivet-holding ability should be applied through the drum. A test along the lines of an ordinary tensile-test made away from the drum probably would not be satisfactory.

In all of the work done at the Bureau, there has not been a single case in which the lining separated from the rivets, although at the conclusion of the severe-service test many of the samples were in a very badly worn and limp condition, frequently being worn-down to much less than one-half the original thickness at the entering edge. The riveting is not required to bear any great strain and, if a little care is used in doing the work and attention paid to avoid pulling the ends of the lining from the rivets when mounting the wheels, no trouble need be expected. A special test, therefore, has seemed unnecessary.

In service, brake linings are found to stick occasionally,

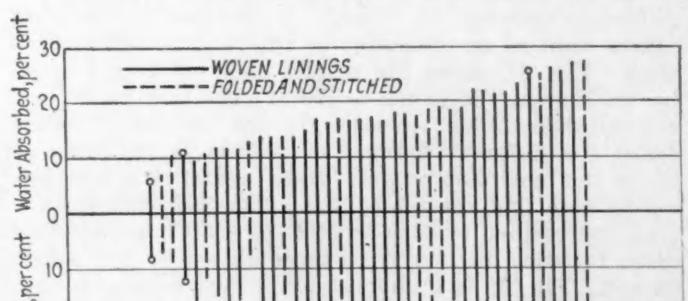


Fig. 23—Relative Absorption of Oil and Water by Brake-Linings

when the brake is left applied to a hot drum. Some car builders have included in their specifications tests to ascertain this tendency that are to be carried out on the car itself, by running a prescribed distance at a fixed speed with the brakes applied. In other cases a test for this tendency has been made by heating samples of lining between metal blocks under pressure and, after cooling, measuring the force required to separate the blocks. This latter method seemed to be less desirable, even for a laboratory test, than one more nearly approaching service conditions. Therefore, standard samples were run in the same manner as for the severe-service test with 6 hp. at 600 r.p.m., for a period sufficient to heat the drum and samples and soften the impregnating compounds. After stopping and cooling, the torque required to move the drum relative to the lining was measured. It was soon found that, with a given lining, the tendency to stick varies with the period of application, and that the period required to develop the maximum tendency varies with different linings. As the heating progresses, the maximum tendency to stick will not result until the compounds have been softened sufficiently. Application of power beyond the point required for the maximum sticking will lead to the changing of the surface layer of the compounds to a dry, powdery or other condition, in which its ability to act as a bond between lining and drum is reduced or lost.

As the nature of the impregnating compounds and their reaction to heating varies, it is understood readily that their relative tendency to stick cannot be ascertained satisfactorily with either of the tests now in use, mentioned previously. This test, as now carried out at the Bureau of Standards, consists in running samples with 6 hp. at 600 r.p.m. for 1, 2, 3, 4 and 5 min. respectively, the load being regulated as promptly as possible after starting; the power is then cut off and the drum allowed to come to rest. The tension between the pressure-arms is increased to 50 lb., as recorded by the spring-balance, and the linings and the drum are allowed to cool for 20 min. The drum is then locked in position by clamping the dynamometer shaft. The torque required to move the brake-shoes in relation to the drum is measured by raising the end of the torque-arm, the force exerted at this point being observed on the spring-balance shown at the right of Fig. 2.

If the pressure on the brake-shoes were released before measuring the torque, the bond between the lining and the drum might be disturbed by the weight of the equipment, the spring of the shoes or accidentally while connecting the lifting device with the torque-arm. To eliminate the effect of this tension, another torque measurement of the force is taken after the bond between the lining and the drum has been broken. The difference between this second torque-value and the first can be used as an indication of the relative tendency to stick. Fig. 21 shows the results obtained with a number of linings. It is noticeable at once that there is a comparatively wide variation in the maximum values found for different linings, as well as in the time at which the maximum occurs. Here, again, it is interesting to note that the folded and rubberized linings as a type, represented by samples Nos. 16 and 17, do not show characteristics distinct from those shown by the woven linings. Fig. 22 is a photograph of two samples of the No. 16 lining shown in Fig. 21. The upper sample showed the maximum sticking for this lining after a 4-min. application; the lower sample had a 2-min. application. The difference in the condition of surface will be noted readily.

Absorption of Water and Oil

Tests to determine the amount of absorption of oil and water were made with samples 5 in. long. After being weighed and measured, they were submerged in oil and water, respectively. The oil or water was heated to 100 deg. cent. (212 deg. fahr.) and kept at this temperature for 1 hr. The samples were then removed, allowed to drain and again weighed and measured.

The liquids were heated to hasten the absorption and thus accelerate the test. The results are shown in Fig. 23 and summarized in Table 2.

TABLE 2—ABSORPTION OF OIL AND WATER

Type of Lining	Absorption, Per Cent Oil	Absorption, Per Cent Water
Woven	14 to 30	10 to 27
Folded and Rubberized	7 to 24	7 to 27
Molded	8 to 17	4 to 24

Measurements to ascertain the change of thickness due to absorption have so far been taken on only a few samples soaked in oil and, where any change was found, it was so small as to indicate that such changes are not likely to cause dragging of brakes having standard linings. In cases where heating may have destroyed the impregnation, the effect may be more marked, but the effect on such linings has not been investigated.

Summary

The work done thus far permits the conclusion that the equipment and general methods developed are satisfactory for laboratory tests to ascertain the relative merits of fabric brake-linings. To establish a suitable test for determining the relative behavior of brake-linings under the more ordinary service conditions where the application of brakes is intermittent and the resultant temperatures are comparatively low, further work is necessary. The severe-service test as used with an uncooled drum is, however, believed to give a fair comparison of the behavior of linings when subjected to severe service. The results obtained indicate very low values of the coefficient of friction as a result of the action of heat on the impregnating compounds.

Very wide differences in the comparative endurance of linings now in use are indicated by the tests, as well as the possibility of marked improvement in durability under severe-service conditions. Owing largely to the users' inability to obtain reliable information of the relative merits of linings otherwise than by prolonged use in actual service, purchases are made almost exclusively on the basis of first cost and without adequate consideration of quality or economy in operation. The general adoption of standard tests, such as have been described, will assist the producer materially in the systematic improvement of his product.

The better understanding by the user of the relative merits of brake-linings, which can be brought about in the same way, will cause an increased demand for the better materials, those giving the most reliable and most economical braking service. The manufacturer will be spared the indignity of having to market materials on the basis of first cost alone, while aware that a relatively slight increase in first cost would permit him to offer materials that will give the user from 50 to 200 per cent more value in braking service.

Chicago and Minneapolis Meetings

IN the month of February two meetings of the Society were held in the Middle West. The first of these was that usually held at Chicago in connection with the automobile show. This took the form of two technical sessions devoted to automotive engineering service subjects on the morning and afternoon of Feb. 1, followed by a dinner in the evening. The other gathering at Minneapolis on Feb. 8 and 9 was the annual Tractor Meeting that is held every year during the week of the National Tractor Show. There were technical sessions on the afternoons of both days and a dinner on the evening of Feb. 9.

The Chicago Service Meeting

The two technical sessions devoted to automotive engineering service subjects held in Chicago, Feb. 1, were the second series of the kind conducted by the Society. They reflected strongly increasing interest in the application of engineering practice to the work of maintaining and operating the world's automotive vehicles and apparatus. It was generally agreed by those in attendance that Engineering Service Meetings should be an annual feature of the Society's work. The scope and complexity of the service industry are increasing daily and the study of its problems will soon be considered equally as important as the other major functions of the automotive engineer. Engineering analysis must be applied to service methods in greater degree. Better tools and practices will have to be created by the men most familiar with motor-vehicle design and construction. The cooperation of the repair superintendent must be sought and closer contact maintained with him by the automotive designer. As stated by President Bachman in opening the Chicago meeting, there should be a better understanding of the operator's problems on the part of the engineer.

The Society's Service Meetings provide an open forum for the mutual discussion of service engineering matters by the constructor and the operator. Careful study of the papers and discussion presented in Chicago last month will reward every progressive designer who aims to have his car or truck render the ultimate in satisfaction to the owner. The first paper of the meeting was presented by B. M. Ikert who chose as his title, A Service-Man's Critical Estimate of Automotive Engineering. He dealt with many specific cases of inaccessibility in current models, slight alteration of which would lighten repair work and reduce labor costs. He called attention to the desirability of studying the design of a new vehicle from the maintenance standpoint in order that the repairs and adjustments made most frequently can be carried out at minimum expense to the car owner. It was the author's opinion that the cars displayed at the 1922 shows reflect more careful thought on features of accessibility and simple adjustment, indicating that designers are more inclined to respect the service-man's desires. In abstracting his paper Mr. Ikert made a plea for the broader education of service engineers and urged the trouble diagnostician to become more familiar with the theory of engine and car performance so that false steps in repairs can be eliminated by better engineering analysis of car troubles.

President Bachman reminded the service-men that the engineer's task is largely one of compromise. He must respect the preferences of the salesman, production engineer, service-man and owner, weighing one against the other and effecting the best compromise in each case. There are bound to be cases where the service-man's request for better accessibility is outweighed by demands for lower production cost. In the opinion of R. B. May a reliable means of studying design changes that facilitate service is to analyze repair parts orders and determine what relation the expense of installation bears to the actual cost of those parts most frequently ordered. It has been his experience that a study of this type reveals many impractical repair operations whose cost could be materially reduced by simple changes in design.

J. Whyte called attention to the lack of standardization in the electric wiring layouts of cars today and urged not only the adoption of a more uniform practice of wiring but also a schematic wire color-standard to simplify electrical repairs. He has found that a closer contact with the repair-man during the early stages of development invariably leads to designs that are most economical from the repair standpoint and cheaper to produce. A. D. T. Libby made an extremely interesting announcement in presenting his discussion, stating that the officers of the Automotive Electrical Association had agreed to stimulate greater use of S. A. E. Electrical Standards in the design of apparatus made by the members of that association.

J. F. Page presented an analysis of the more important organization matters in a modern service-station, which by careful study or by neglect can wholly determine the attitude of the car-owner to that station. While his paper was not of an engineering nature, Mr. Page's reasoning appealed strongly to the members since he presented the views of the man who is in direct contact with the general public. He said that the owner can reasonably demand and expect courteous and intelligent treatment, proper mechanical work, quick service, dependable promises, fair prices and correct and understandable bills. The particular provisions necessary to satisfy these expectations were outlined, the three essential factors being trained personnel, adequate equipment in floor-space and tools and an effective system. Certain unreasonable requests will continue to be made by owners but Mr. Page felt sure that these will be relatively few in number. He stated that the public is fast becoming motor-wise and that the present-day active competition is forcing improvements in accessibility and adjustment with resultant economy in repair costs. Organization of the service-station along business-like lines can no longer be avoided if a company expects to survive in a buyer's-market.

President Bachman believed that Mr. Page's paper made possible a clearer definition of service as "the rendering of facilities for the efficient and economical operation of automotive apparatus." Past-President Beecroft strongly urged greater appreciation of the value of a business man's time when he enters the service-station. The delay he experiences in placing his order or in having simple adjustments made should be reduced to an absolute minimum. Mr. Beecroft reminded those present that the matter of rendering efficient service is becoming more important in the sale of all goods today. It is one of the principal elements in our competing with other nations in foreign markets. Standardization is another important factor, since the use of standard parts

and materials facilitates the servicing of automotive vehicles in distant points without the accumulation of a vast stock of repair parts.

Body Service and Garage Equipment

A paper enumerating the many service advantages resulting from motor-truck body standardization was presented by C. B. Veal and C. M. Manly under the title, Commercial-Body Supply and Service. The authors described a method of constructing motor-truck bodies by assembly from a series of interchangeable standard units and stressed the economies made possible by this departure from the more general practice of designing and building custom bodies to suit the individual whims of the truck owner. These standardized sectional bodies also hold advantages for the dealer and the service-man. Repairs resulting from collision can be made with little delay since complete interchangeable units, such as side-panels and roofs, can be kept in stock and readily assembled into place. A strong plea was made for the adoption of standard body-mounting dimensions by the truck builders as one means of reducing the ultimate ton-mile cost of automotive transportation. J. E. Schipper said that the tremendous stocks of raw and partly fabricated material maintained by body-builders in anticipation of special orders is largely responsible for high body prices. If, through standardization, the body-builder could be assured of a market for a particular body type on many makes of chassis, he could then risk producing to an economical schedule and reduce his overhead and detail costs. J. R. Willis did not believe that the complete standardization of truck chassis body-dimensions is practical on account of the wide variation in weight per cubic foot of various commodities and materials. A truck for hauling empty barrels must necessarily be longer than one hauling an equivalent weight of sand. He felt, however, that all driver-cabs could be made interchangeable between chassis of different makes and capacities; also that spring and wheel locations relative to the frame might follow a uniform practice and simplify body mounting. G. S. Cawthorne said cab standardization is not only feasible but would soon be an established fact. In closing the discussion of the paper Mr. Veal called attention to the existing S. A. E. Recommended Practice for Commercial Body-Mounting Dimensions and urged truck builders to adopt this standard more generally with the idea of lowering the ultimate cost of truck transportation and thereby stimulating truck sales.

H. C. Buffington's paper, The Progress Made in Garage Equipment, served to acquaint the members with a number of specialized tools, including jacks, engine stands and wrecking cranes that are now developed for use in garages and service-stations where lower repair costs are considered. In his opinion this development has only started and the near future will discover a large number of efficient devices for the easier handling of automotive units in process of repair. Mr. Buffington called attention to many points encountered in the design of this garage equipment that warrant special attention on the part of the Standards Committee of the Society. It was brought out in the discussion that car jacks cannot be of the same height for all cars because no provision has been made for the jack-head to be at a uniform distance from the ground. In extreme cases it is not even possible to apply the same jack properly under the front and the rear axle of a given car. Howard Campbell read some discussion he had prepared after a comprehensive survey of garages and service-stations to compare tools, operations and methods. He was surprised at the lack of uniformity in methods pursued by different stations in servicing the same make of car. He predicted that the car builder will soon give as careful consideration to the standardization and design of tools for the repair of his vehicles as he has given to the tools used in car production. Standardized operations, tools and methods lead to standardized service charges and this assures owner satisfaction from the price angle. W. C. Allen stated that $68,000,000 worth of garage equipment had been sold in 1921 and that 40 per cent of this equipment had to be discarded as unfit. This situation indicates, of course, lack of cooperation between the manufacturer of this equipment and the repair-man. It must be corrected by more intimate knowledge of the work to be done by the respective tools and fixtures. One member urged the adoption by all service-stations of a flat-rate charge for periodic lubrication of cars and trucks. The average owner is negligent in the matter of proper draining and refilling of the crankcase, transmission and rear axle, but would take advantage of an oil-while-you-wait service at a reasonable cost.

The general feeling prevailed during both service sessions that automotive repair and maintenance are fast becoming a major function of the industry. In periods of depression the service branch of the business is busier than in times of prosperity. Owners pay more attention to the adjustment, lubrication and care of their cars, for they are anxious to lengthen the life of the vehicles they own and reduce their cost of operation. The growing importance of service work, particularly in its engineering phases, demands that even closer attention be paid to the problems of the repair-man. He can be brought into closer relation with the designer at meetings such as those held in Chicago. It is the intention of the Council and Meetings Committee to enlarge the scope of such meetings to be held by the Society from time to time.

Chicago Dinner

At the dinner on the evening of Feb. 1 President Bachman referred to the sessions held during the day as having given a broader and clearer conception of the engineer's responsibility as to cooperating with other divisions of the industry in assuring that motor vehicles are designed not only in accord with classroom and laboratory theory but to meet the stern requirements of practical use. He appealed to the members to uphold the ideal of service to the end of surmounting quickly the problems of today and the engineer taking his proper place and shouldering his full responsibilities.

Toastmaster Horning said that the industry was facing the same sort of decision that the Generals of the Allies faced in the Battle of the Marne, but that no man can afford to look into the future with eyes of fear. He sounded the signal for dispelling the recent gloom and despair and for going forward with courage to real victory, the psychology of the period being that there is no need for anything but victory ahead.

He quoted the dictionary as defining an engineer as a manager, notwithstanding the casual interrogation, How Can a Man be an Engineer *and* a Manager? He pointed out that occasions like this dinner, at which General Manager Grant, of the Dayton Engineering Laboratories Co., addressed the members in such an informative and inspiring manner, made it possible for the engineers to function in the highest way to accomplish the greatest things in the industry.

The members were very much gratified and encour-

aged by Mr. Grant's remarks, as well as greatly amused by his similes of highbrow production practices. His outline of trade development and vicissitudes during the last decade and his analysis of the industrial outlook, which are reproduced in this issue of THE JOURNAL under the title, How the Engineer Can Help Business, held much of clarity and conviction. It is recommended that the members give careful study to what he said and take home to themselves his admonitions and advice which are undoubtedly very pertinent to the work of all automotive engineering departments. The thing that Mr. Grant emphasized most perhaps is that it is essential that the activities of the financial, production, sales and engineering departments be closely knit together in team-play for the accomplishing of the purposes of the company as a whole, the head of each of these departments having a good working knowledge of the problems of all of the departments.

THE WORLD ECONOMIC SITUATION

H. G. Moulton, of the University of Chicago and editor of *Chicago Commerce*, presented some phases of the present business situation from the standpoint of the professional student of political economy and as they appear to the bankers of the world. He said:

> European nations, unlike our own, have long been in the habit of making budgets but, unfortunately, since the war they have not been in the habit of balancing them. In the year 1920 not a single nation in Europe, with the exception of Great Britain, was able to balance its budget; every one of those nations spent money far in excess of what they were able to raise from taxation, with the single exception of Great Britain. Even Great Britain in the year 1921 was faced with the inability to raise revenue from taxation sufficient to meet expenditures.
>
> France can raise from taxation somewhere between 18,000,000,000 and 20,000,000,000 francs. The total French expenditures are still running from 45,000,000,000 to 50,000,000,000 francs. In the year 1921 alone the French deficit amounted to 35,000,000,000 francs. In the nations of Central Europe it is a case of printing government paper money, sometimes by the governments themselves, sometimes through the intermediation of the central banks. In other countries it is done on the basis of short-time loans from the banks, and in part on the basis of new bond issues placed in the investment markets. But in any event it means increased borrowing.
>
> After 4 years of war the French debt had increased from 34,000,000,000 to 150,000,000,000 francs, almost quadrupled in the period of the war. It has more than doubled since the Armistice. And yet there are very many writers who tell you that France is coming back to normal conditions with enormously rapid strides. It is the budgetary situation in France, Italy, Belgium, Germany and the nations of Eastern Europe that has given the statesmen of Europe the scare which has led to the calling of an international conference at Genoa.
>
> France sees that she cannot balance her budget out of her own taxation revenues, and therefore insists that she receive reparations from Germany. Meanwhile Germany's budget is more seriously unbalanced than that of France and she insists she cannot pay reparations. Great Britain stands in what may be called a neutral position on the matter at the present time. The Reparations Commission, the allied experts and most of the students of the world have agreed that Germany at the present time cannot pay reparations in very large amounts. The only way in which a nation can pay debts beyond its borders is through exporting goods across its borders. Germany cannot pay with gold. The total gold supply of Germany is less than $250,000,000. That is less than sufficient to pay the indemnity for a single half-year. If, therefore, Germany is to pay, she must pay in goods. But the main truth is that not a single nation is willing to receive the goods with which alone Germany can pay. In other words, all the allied nations themselves, when it comes to a showdown, do not want Germany to pay. Lloyd George stated this officially last winter; Premier Briand stated the same thing in almost identical words, and it is perfectly evident to anybody who will read the facts that that is the case.
>
> TARIFF WALLS
>
> France has raised a protective tariff for the express purpose of keeping German goods out. On the other hand, she would be willing to see some of the German goods shipped into Great Britain to permit Germany to pay reparations to France. But Great Britain has an anti-dumping tariff bill designed specifically to keep German goods out of Great Britain. Both France and Great Britain would be glad to see Germany ship goods to the United States and thus get the means of paying reparations to the Western European countries, but we have an emergency tariff law to keep German goods from inundating our markets and disturbing our domestic conditions. On the part of the United States, those who believe that we really want European debts paid to us and would like to see Germany paying reparations say it is not after all necessary for the United States to receive those goods; that the matter can be accomplished in roundabout ways. Therefore, the goods should be shipped to South America. But the American manufacturers who are looking to South America as their best chance to expand their exports in the face of a declining European demand do not want German competition to drive them out of the South American markets where they have already been obtaining a foothold. So they say, If they cannot sell those German goods in South America to pay reparations, cannot they sell them in Poland, in Czecho-Slovakia, in Russia? That question was propounded by an American economist to a high French official at the time of the Armistice. The reply was, No, France is not willing to see Germany regain her standing in the Eastern European markets. France is looking with eager eyes to the expansion of her own foreign trade in that section of the world.
>
> Russia is out of the question so far as France is concerned, and the United States also is looking to Russia to find an outlet for its excess manufacturing capacity; and the same is true of the great British industries. If they cannot get into Russia, what about Asia, China? When the Celestial Empire comes within the folds of commercial civilization, when that great giant of the East awakens, is that not the place for Germany to sell her goods? In the years before the war there was an international banking consortium for the development of Chinese resources. Five nations, Germany, England, France, the United States and Japan, were in that. Since the war Germany has been excluded. The United States and the other nations involved have become a four-power consortium for the exploitation of those resources.
>
> That is the truth of the matter, as it is recognized in England everywhere. England, therefore, is willing to see the reparations question scrapped. France is hoping against hope that she will save her own financial position by receiving German reparations. On the other hand, England sees that the thing that England needs and the thing that the world needs is a restoration of a prosperous Central Europe. She is looking forward to a restoration of trade with Germany and Central Europe.
>
> We have in place of a powerful and thrifty Germany on the economic side now a decadent Central and

Eastern Europe. In the 44 years between the Franco-Prussian War and the outbreak of the Great War in Europe in 1914 a remarkable development took place in the heart of the Continent of Europe. Germany, until that time, was a weak, poor, agricultural nation, with no great industrial development whatsoever. In the brief space of 44 years there occurred a remarkable economic evolution. That nation advanced from a population of 40,000,000 to a population of 68,000,000. By linking science and industry in a remarkable way the standard of living of those 68,000,000 people was raised to a much higher level than ever before, and Germany not only became a powerful competitor of the other nations in selling goods in the markets of the world, but Germany became by all odds the best market for English goods. Germany, as a matter of fact, exported something like 10,000,000,000 marks worth of goods annually to the rest of the world, but imported 11,000,000,000 marks worth annually from the rest of the world.

CENTRAL EUROPE CONDITIONS

Germany became the organizing force for all the rest of Central, Southeastern and Eastern Europe, from the North Sea to the very borders of Asia. It was from the financial offices of Berlin, Hamburg, Frankfort and Vienna that the vast economic organization of the whole of Central and Eastern Europe radiated. That organization, as the result of the settlements that have followed the war, has been largely broken down. Some of the reasons for this are political and some economic. A unified economic system was treading beyond national bounds. It has been torn down, and a great reduction in the standard of living of the whole region has resulted. Mr. Hoover has estimated that even in Germany the standard of living is now not more than 60 per cent of what it was in the days before the war. It is that situation in Germany, with the lack of purchasing power there, that has compelled England to shift her position with reference to the reparations issue completely. England is opposing the policy of France.

I hold no brief whatsoever for the German political system that existed before the war. I was as glad as anybody to see that broken once and for all, but the situation in Europe now requires us to view it with sanity, because, in the view of the greatest British statesmen, bankers and economists, the very fate of European civilization is at stake in the solution of the problems involved.

POSITION OF THE UNITED STATES

How does that come back to the United States? Mr. Grant told you that our export trade to Europe in the year 1921, as far as agricultural produce is concerned, held up remarkably well. As a matter of fact, the total number of bushels of wheat exported in 1921 was in excess of what it was in 1920. But bear in mind that the price dropped from roughly $2 to $1 a bushel, with the quotations now below prewar levels at the farm. That has given rise to considerable discussion among economists and bankers. I am informed that Europe is willing to take large quantities of wheat, but insists upon getting it at a very low price. There is an extremely sluggish demand. With the Government purchasing power in the field Europe was able to take advantage of the situation at every step and reduce the prices to a level where it could buy. That is the explanation on the demand side. On the other hand, the American farmer pressed relentlessly a huge supply to market all the time, partly because of the necessities of the farmers themselves and partly because of the insistence of bankers that farmers liquidate their loans. On the one side, a tremendous pressure of supply; on the other side, a very halting demand.

If the farmers of the United States cannot sell their grain at a good figure, obviously they cannot buy the same quantity of produce from the local retailers that they would otherwise buy. The local retailer cannot buy the same volume of commodities from the wholesalers of the distributing centers, and of course the wholesalers of the distributing centers cannot buy the same volume of produce from the manufacturers. That means that the manufacturers cannot employ the same number of laborers that they otherwise would, and that those laborers who are out of jobs cannot buy at their local retail stores the same quantity of goods that they otherwise would, and those retail stores cannot pass back the orders to their wholesalers and manufacturers, and so on around the circle. That is perfectly clear and simple.

IMPORTANCE OF EXPORT TRADE

Take the cotton situation. There is practically identically the same thing there. Sometimes people say that the total foreign demand is only 8 or 10 per cent of our total domestic trade and, therefore, we shall not need to worry much even if it disappears. It is over 50 per cent in the case of cotton and roughly over 30 per cent in the case of grain. Let the foreign demand for cotton drop still lower, and the agricultural depression in the South will be more severe. You may recall the "Buy a Bale of Cotton" movement in 1914, at the outbreak of the war when the cotton exports were almost completely eliminated. Cotton dropped to 6 cents per lb. Six cents a pound meant ruin to the cotton industry. It meant inability on the part of the dealers to pay the bills of wholesalers in the centers of the North; it meant inability on the part of the wholesalers in the North to pay their debts to the banks; and so the banks and the business men of Northern cities, instead of trying to drum up more home business, tried to get a "Buy a Bale of Cotton" movement started to raise the price of cotton. What happened when in less than a year the great European demand for cotton reasserted itself and the cotton rose from 6 to 15 and 20 and 42 cents per lb.? Plenty came back to all the Southern region. Not only did they pay off their past bills but they expanded their scale of living; they bought things and developed their farm property in a way never known before. That shows that the United States is linked indissolubly in trade relations to Europe. It is impossible for us to have real prosperity so long as Europe is going in the opposite direction.

THE WORLD AN ECONOMIC UNIT

I agree heartily with what Mr. Grant has said; that it is up to every one of us to do his level best in his own way to improve the situation as he finds it. What can we do with reference to the European situation? We have a foolish notion in the United States that Europe is no concern of ours, that we should live in isolation from the rest of the world, if need be. The plain truth of the matter is that the world is an economic unit now. The farmers of the Country are coming to understand that. The bankers know that the world is an economic unit. Some of these days the irreconcilables in Congress will realize it.

I attended a meeting in New York City last week to consider the question of whether the United States should participate in the Genoa Conference. This is the situation that existed: The United States could not send to the Genoa Conference any official representatives with power to act for it for the simple reason that Congress would not bestow any such authority upon any American representatives. There is no use of our going to the Genoa Conference unless we can join in working out some solution. Every nation has to do its part and take its responsibilities. If we are to have some kind of international organization for the solution of the problems before us, as some of the

European governments now insist, we must have some kind of international economic machinery for dealing with those problems. The duty of the American business-man in 1922 is to recognize that the European problems must find a solution.

DOMESTIC PROGRESS

So far as the domestic situation is concerned, unquestionably we have progressed far in the past 12 months. The progress henceforth, as I see it as an economist, will leave us in a gradually better position, provided the European situation does not grow steadily worse. As manufacturing prices fall toward the level of agricultural prices, there will be a gradual increase in the purchasing power of the farming communities. Many other factors are working toward the same direction. But controlling all is the condition of the European budgets, and the condition of the European budgets will remain what it is, the nations going further and further toward the condition of bankruptcy, until some thoroughgoing, comprehensive, economic program is worked out.

I want to see the United States stand shoulder to shoulder with England in a solution of the problems, because in that I think lies not only the hope of the Anglo-Saxon people in the next 5 or 10 years, but the hope and prosperity of the world as a whole.

MINNEAPOLIS TRACTOR MEETING

Much interest was shown in the meeting of the Society held at Minneapolis during the National Tractor Show Week. The first technical session on Wednesday afternoon, Feb. 8, was devoted to the application of the tractor to the building and maintenance of roads. C. M. Babcock, commissioner of highways of Minnesota, addressed the members and gave some interesting statistical data that indicated the extent of road-building operations in that State during 1921. He urged those present to use their influence to keep the matter of highway construction and maintenance out of politics. Road building is one of the most extensive engineering operations in the United States and it is essential that it be conducted on business-like lines. Each State must interest itself in the road programs of its neighboring States, keep them active in the road-building business and arrange trunk highways with proper relation to interstate transportation. According to Mr. Babcock, only 35 States were able to absorb their share of the Federal-aid fund for road construction in 1921. He fears that this condition may result in a substantial reduction in Federal appropriations for the coming year and presented it as another reason for each State maintaining interest in the road-building activity of the other States.

During 1921 the State of Minnesota expended $33,656,145 in extending and maintaining its highway system. This fund was raised from State automobile license fees, county and township taxes and the Federal-aid funds. It enabled the State Highway Department to grade 765 miles of road, gravel 497 miles and pave 109 miles. A total of 885 miles was regraveled and 1131 miles was reshaped. The work included the patroling and inspection of 6855 miles of highway. It is readily appreciated how helpful this work is in an agricultural State like Minnesota. The highway funds available did not warrant the expenditure of large sums of money on snow removal. Mr. Babcock said that it is better to let the highways remain somewhat blocked for a few weeks in mid-winter than to spend maintenance funds for snow removal and have the roads go to pieces from lack of proper repairs. The highway dollar in Minnesota is derived from the following sources in the proportions given: County taxes, 32½ cents; township taxes, 20½ cents; motor-vehicle licenses, 16 cents; road bonds, 12 cents; Federal aid, 9 cents; State taxes, 6 cents, and city taxes, 4 cents.

The paper on Operation of Automotive Equipment in Road Construction and Maintenance, given by A. C. Godward, contained some extremely interesting cost data on tractors and trucks operated by the Minneapolis Park Board. Mr. Godward had compiled figures to impress the tractor designers with the value of first-cost of automotive equipment compared with its operation and maintenance expense. His data indicated that first-cost represents only 20 to 30 per cent of the total annual cost of operating a 5-ton truck or a 10-ton track-laying tractor. The ratio of fixed to operating expense was 1 to 2 in the case of the truck, 1 to 3 in the case of the tractor and 1 to 6 in the case of a ¾-yd steam shovel. From these data it can be readily seen how much worth while it is to pay a higher price for new equipment provided its operating and repair expense is reduced by the guarantee of better quality, dependability and ruggedness. Mr. Godward felt sure that automotive designers would always find the road engineer willing and glad to furnish cost information for the guidance of the tractor builder. From his own figures he could define certain development in tractor design that would lessen operating expense and establish the tractor as a more economical unit. It is also the practice of the road engineer to offer suggestions gathered from his field experience and pass them on to the man responsible for the design of the unit he uses. In response to a question, Mr. Godward stated that the cost system he is using had been laid out by his own organization, is adaptable only to reasonably small road operations and probably could not be followed as a standard. In connection with Mr. Godward's statement that tractors in his service work 1600 hr. per year and have a life of 5 years, or an equivalent of 8000 working hr., A. W. Scarratt remarked that, since the average automobile would travel 100,000 miles in this same period, this is an indication of the ruggedness built into the modern tractor. Mr. Godward agreed and attributed the results largely to the excellent care given these machines. They were generally operated on heavy work such as elevating graders, snowplowing and pulling of stumps. In addition to continuous attention to adjustments and lubrication, each machine was thoroughly overhauled in the winter before starting the spring road-work.

The adaptation of the tractor to road-grading work was treated by C. O. Wold. He believes that although the tractor is well suited to the hauling of all sizes of grading machinery, the horse competes strongly with it when the grader-blade width is less than 10 ft. When the work in hand warrants the first expense it is always economical to use tractors with graders of large blade-width; a 12-ft. blade will always build a mile of road at less cost than a 10-ft. blade. This fact is much in favor of the tractor for grader work. In analyzing the sales of grading machinery Mr. Wold said that approximately 2500 machines of the larger sizes are sold annually. All of these machines are for tractor use. On the other hand, 15,000 of the smaller graders are marketed annually, nearly all of them being of the horse-drawn type. The combination of grader and tractor in a single machine did not strike Mr. Wold as being feasible since, at times, it would necessitate the tractor working in the ditch where it might not be stable. A slow tractor speed, about 2 m.p.h., was recommended for this class of work. Although opinion on the proper design of lugs

for tractor wheels varies greatly, Mr. Wold has found the simple cone lug is preferable in road-maintenance work. Tractor wheels should be made heavier for road-work than is the practice in the case of agricultural machines. Answering a question, Mr. Wold said that the recent low cost of horses and feed had reduced the purchase of small tractors for the lighter maintenance work, but that the larger units are still in demand for the heavier duties of road building.

The experience with tractors of a contractor was given by R. C. Shoen in his paper, Practical Road Construction. He applies tractors extensively in his road-building operations and is a confirmed believer in their superiority to horses for this class of work. He employs tractors exclusively on all grading machines. He uses them to transport his camp houses and equipment as the work advances, having found camp mobility a large factor in the reduction of road-construction costs. His tractors have been utilized frequently to move very large boulders that could not be handled with horses; they performed to marked advantage in turning time; and were superior in the finishing operations. The tractors cost $40 per day to operate, compared with $46 for horses doing the same work. Under conditions favorable to the horse, Mr. Schoen found it cost 1½ cents less per cu. yd. to move dirt with the tractor. One of the interesting statements he made was that he adhered strictly to the builder's recommendations on grades of lubricant to be used with the tractors. He attributed a good part of his success to this care in selecting and using good lubricants.

Mr. Schoen pointed out that one automotive link is missing in the road-building business, a suitable machine for hauling dirt where operations are necessarily limited to travel over loose earth. The motor truck is capable of hauling gravel, but in this case all of its travel is over hard surface. One solution of the problem would be the development of a special dump trailer to be hauled by the tractor.

Following Mr. Shoen's address, motion pictures were shown of tractors engaged in road construction and maintenance operations.

At the technical session devoted to agricultural applications of the tractor the first paper, by G. Douglas Jones, was on The Relation of the Tractor to the Farm Implement. Mr. Jones directed the attention of the members to those lines of tractor design development that impressed him as possessing the greatest promise for the future expansion of the tractor industry. He stated that there are 4,000,000 farms in the United States having an individual area of 50 to 200 acres, and that, since these represent 80 per cent of the total number of farms in this country, their owners logically constitute the principal body of tractor buyers. The majority of these farms are operated as producers of diversified crops and a great many types of implement are required to work them. To fulfill the requirements of the farmer raising diversified crops on these smaller farms, it will be necessary to develop small tractors of light weight, capable of handling all of the power work on the farm. They must be adaptable to the cultivation of row crops and not be designed for plowing work only. Although Mr. Jones acknowledged that his specifications represented an ideal, he believed that they pointed the way to the accomplishment of a broader application of tractors to farm work and a consequent expansion and stabilization of the tractor industry. His paper elicited very active discussion. A. W. Scarratt was of the opinion that the concentration of all functions into a single type of tractor is not practicable, and that two types would always be required for farm work, a heavy unit capable of handling plowing operations or other work demanding a rugged machine subjected to heavy drawbar loads, and a lighter machine for harrowing, intertillage work, mowing, binding and belt duty. In reply, Mr. Jones expressed the hope that the plow will be superseded by a far more efficient implement that will make possible more direct application of automotive power to the preparation of the soil. Prof. J. B. Davidson concurred in this hope. He had noticed that there are two schools of tractor designers. One group aims only to replace the horse on the farm and accepts the present-day horse-drawn implement as the final stage of implement development. The other group is studying the possibilities of a more direct application of automotive power to soil tillage, cultivation and harvesting. Professor Davidson has faith in this second group and feels that eventually they will perfect lightweight tractors and implements that are not only more efficient on the farm but more nearly automatic in operation. Frank N. G. Kranich believed that more attention should be given to the operation of farm tractors and implements as single rather than independent units. Replying to Professor Davidson and Mr. Jones, A. W. Scarratt stated that it would be a difficult task to convert the farmer to the use of an implement other than the plow for tilling the soil. Farmers as a class are reluctant to accept any development that tends to revolutionize practices of century-long standing. E. R. Greer suggested that the heavier tractor duties such as plowing might be handled by community-owned tractors of the heavy type, leaving the lighter and diversified work to the all-purpose machine owned and operated by the individual farmers. Professor Davidson said that community ownership of tractors has not proved practical in the majority of cases and is not to be recommended. Contract plowing with tractors is practical, however, and feasible in the scheme suggested by Mr. Greer. Professor Davidson felt certain that a compromise type of tractor can be used successfully, although its power may be slightly inadequate for plowing and excessive cultivation. Such a machine will possess greater utility and be of much value to the farmer of diversified crops. J. S. Clapper also expressed favorable interest in Mr. Jones' ideal tractor. He stated that 45 per cent of the farm land in this country is planted with row crops which represent 55 per cent of the total crop value. It is not possible to convince the diversified-farm owner that a single-purpose heavy-duty tractor is suitable for this work. Present types of tractor are satisfactory for work in the grain fields, but the tractor engineer must establish a closer relation with the row-crop farmer, familiarize himself with the numerous functions this farmer expects his tractor to perform and then perfect an automotive unit that will meet the real need economically.

In the second paper of the Thursday meeting, P. M. Heldt outlined the history of engineering standardization in the automotive industry and urged not only a more extended application of standards in tractor design but a greater interest in the work of creating additional standards in the tractor and farm-power fields. He cited many instances of material savings in production cost effected by the use of S. A. E. Standards in the passenger-car industry. He pointed out the value of S. A. E. Standard steels to the tractor builder, and mentioned the standard magneto mounting as an illustration of passenger-car standards that are applicable to tractor design. Hitches, belt speeds, screw sizes and lug attachments were mentioned as features of tractor design in which stand-

ardization is of value. In closing, Mr. Heldt again urged better cooperation between tractor producers in the extension of the Society's tractor standards as a means of reducing production costs and meeting the demand of the farmer for lower tractor prices. This paper was followed by a general discussion of the S. A. E. Steel Specifications and their application in the construction of farm tractors. Chester S. Moody expressed appreciation of the steel standards but hoped that further investigation would be made of the penetration of heat-treatment in sections exceeding $1\frac{1}{2}$ in. in diameter since these are often encountered in tractor construction. C. F. Clarkson advocated a more thorough understanding of the advantages of standardization between the engineer and those who were his superiors in the executive branch of the business.

Tractor and Plow Reactions to Various Hitches was the subject of a very valuable and interesting paper presented by O. B. Zimmerman and T. G. Sewall. The authors had made an analytical study of the forces and reactions in effect when single and multiple plows are being drawn by a tractor. Formulas were derived that are readily applicable to the solution of problems of tractor stability against overturning. Using the methods developed in the analysis, it is possible to find more readily the answer to such questions as: Shall the tractor be run on the land or with one wheel in the furrow? Should the tractor hitch be low or high in relation to the ground? Where is the center of plow reaction? The reaction of the plow to forward motion is resolved into three major components: one across the furrow; another down the furrow; and the third the vertical force. These in turn are considered as acting at one point that the authors designate as the center of plow reaction. The effect of varying the direction of the line of draft through this point is studied in a way that shows the necessity of exercising care in the selection of a common hitch-point for the draft of multiple-plow units. Diagrams and tables are given that enable the engineer to determine whether long or short hitches are desirable in a given case and what relation the hitch center should bear to the center of plow reaction. It is shown, for example, that if the tractor is operated on the land in preference to the furrow, a long hitch is desirable with two and three-plow units. The forces that tend to overturn the tractor are carefully analyzed and the effect of engine torque, drawbar reactions, rolling resistance, slippage of drive-wheels, gradient and weight of operator is clearly pointed out. Two representative tractors reported in the Nebraska tests are compared for stability by the use of the formulas developed in the paper. Stability curves are constructed for each of these machines showing their relative tendency to overturn under the same operating conditions. Mr. Zimmerman stated that while the analysis might be more closely and correctly refined, the main features developed clarify and segregate the primary influences affecting the several actions and reactions, whose net sum might be approximately ascertained under any set of conditions, by applying the simple formulas given. The analysis set forth also establishes a definite method of attack for a more correct determination of the most suitable hitch and the selection of proper wheel lugs.

The Dinner

O. W. Young, second vice-president of the Society for tractor engineering, presided at the dinner held at the Hotel Radisson. E. A. Merrill, who was toastmaster, introduced in a highly felicitous manner the speakers of the evening, the first of whom was E. G. Quamme, president of the Federal Land Bank of St. Paul, Minn.

Mr. Quamme said in part:

The agricultural industry of the United States, which is our foundation industry, is in a bad way and has been for 2 years. Two things have contributed largely to disorganizing it, the first being the rapid and drastic decline in prices of farm products, and the second the inflation that entered into land values. Many who have studied the situation carefully have thought all along that it was a great mistake to deflate the value of farm products so drastically and so rapidly. It would have been better for our Country if we had moved a little more slowly, for the American farmer and the villager constitute the best market that American industry has. While they constitute only 37 per cent of the population, they purchase fully 60 per cent of all the manufactured products sold in this Country.

When there is a mortgage of \$100 an acre bearing 7 per cent interest, there is a charge of \$7 per acre on that land that must be paid before anything else is paid. While inflation entered into land values, it entered also into governmental costs, school districts, townships, counties, State government, until the taxes had gone up from \$40 per farm of 160 acres to as high as \$3 an acre, or \$480 per quarter-section. Twenty years ago \$3 per acre was considered good rent for a farm.

The gross producing power of this Nation is \$40,000,000,000 a year. If our governmental costs are \$4,000,000,000, one-tenth of the gross earning power of the entire Nation is used for governmental purposes. We do not realize the full importance of this yet, but we will as time goes on.

After the war of 1812 we had a down-curve, as all of you who have studied economics know, for 30 years. After the Civil War we had a down-curve of 30 years and an up-curve of 20. In times of peace and when there is no obstruction on the part of the government or otherwise by regulation, there is a relative value between all things, between the bushel of wheat and the monkey-wrench, and the bushel of wheat and any other article. That relation has now been thrown out-of-joint; it does not exist. Food products, farm products and raw materials have been deflated down to the rock-bottom, below anything that we have seen in the last two decades and much below the cost of production.

Our industry has been developed to such a point that if it is operated at 60-per cent efficiency it will satisfy all the needs of our Country. If it is to be operated at 100-per cent efficiency we must find a foreign market for 40 per cent of our products. Agriculture also has been efficiently organized and developed. We do not need 80 per cent of the efficiency that the agricultural production in this Country has attained to feed our Nation. If it is to operate 100 per cent., we must find export for over 20 per cent of our products.

From 1910 to 1920 the farm-mortgage indebtedness of the United States increased 137 per cent. The farm values, including both land and improvement, increased only 117 per cent. The mortgage indebtedness of the United States in the last 10 years increased much faster than the wealth and the population. In other words, we were mortgaging the future. Much of the increases in value during 1916 and the four following years were fictitious, not being based upon income.

AGRICULTURAL AND FINANCIAL SITUATION IMPROVING

The agricultural situation today is not so bad; it is rather hopeful and much better than it was last year or the year before. We are past the worst. The worst period we have left is that between this and harvest time. We need cooperation and coordination of effort on the part of all citizens and all classes to carry

through until we get a crop. Then we will be on the uptrend and will have seen the worst.

As to how long it will take to readjust, bring the crops back again in regard to all things, I think it will take at least 20 years, but we will learn to adjust ourselves to these conditions and the worst will be over. Industry will be operated not on a 100-per cent basis but will start after a while on a 20, 30, 40 and 50-per cent basis, and so on, and if we can find more markets we can extend our operations.

The financial situation is improving wonderfully. It began to improve in the East. Reserves are getting into good shape. There has been good liquidation. We have laid a solid foundation so far as financing is concerned. It is the best that we have had in many years, and is getting better every month. There is a good demand for mortgages, which will help to stabilize the agricultural situation.

It was absolutely wrong for the Government to encourage the counties, the States and all public subdivisions to build courthouses, schoolhouses and the like at the time the war ended, when we needed capital and material and did not have labor enough to go around. Many people said at the time, "For heaven's sake, when we cannot find enough labor for essential industry, let us not inject this political and public work; let us save it so that if hard times come later on, we will have it." We have created billions of dollars of tax-free securities and spent the money lavishly and foolishly. Now is the time to stop and safeguard what capital we have left for industry.

The automotive industry is one of the largest industries in this Country and one of the largest in the world, but I believe that it was overdone.

FREIGHT RATES AND COAL PRICES

What are the two main things that stand in the way of immediate resumption of business? They are railroad freight-rates and the price of coal. We have always thought very highly of our wheat crop in Minnesota; when people of the East think of Minnesota, they think of the wheat crop. It is important, of course, but it is not one of our greatest crops. Last year we sold about $170,000,000 worth of butter. Our wheat crop amounted to about $30,000,000. This season we bought $30,000,000 worth of coal in Minnesota. With the present price of coal we have to trade off our magnificent wheat crop in this State to have fuel for 1 year. Necessity, the mother of invention, drives people to many things. It will drive us to using lignite coal mined in North Dakota and Montana. Processes are already under way that will prepare that coal for producing iron ore and for every other useful thing that requires grate fuel. It will not be long until we can declare our independence of Pennsylvania and West Virginia.

Our railroad division points were laid out on the basis of a 10-hr. day. A train would run so far in 10 hr. Then there came the 8-hr. day on the railroads. This necessitated extra crews, time and overtime, time-and-a-half, and pay-and-a-half for time-and-a-half. Unless the freight rates are readjusted, the whole industrial map of the United States will be changed. Large areas of territory will be depopulated. There are manufacturers in New England who cannot afford to stay there any longer because they have to ship their products into the interior of the Country. The food supply comes from the interior, and it costs so much to send it to these people that they cannot afford to pay wages high enough to continue in business, maintaining the high standard of living that their employes are entitled to as American citizens. It will be better and cheaper for us, if necessary, to subsidize the railroads, and make them go back again to their freight charges of 1912, 1913 and 1914.

J. L. Record, chairman of the board of directors of the Minneapolis Steel and Machinery Co., gave a comprehensive analysis of general business conditions, saying in part:

> While the agricultural situation in the corn-producing States is exceptionally bad, there are other localities where it is exceptionally good. In California they have never experienced such prosperity as now. In the vineyard sections they have produced wonderful crops and sold them at prices never heard of before.

RECOVERY IN WHEAT-PRODUCING TERRITORY

> In some of the cotton-producing territory where crops were fairly good and harvested early and prices were fair, there is a substantial start toward recovery. The wheat-growing sections of the Middle West, while subjected to a decrease in the price of their products, have not suffered much from the decline in the value of the farms because there has been there little inflation of values. One crop in that territory with a good fair price will see it well on its way to recovery. I believe we shall have satisfactory business from this territory very much sooner than from the corn-producing sections.
>
> Reliable information comes to us from the East indicating that the situation there is improving steadily; because of its diversified farming this territory did not suffer to the same extent as the West, and satisfactory conditions will prevail soon. This advice comes direct from the tractor and implement dealers. Trade is fairly satisfactory in the East now.
>
> Taking the agricultural situation over the Country as a whole, there is nothing about which the farmer or the community should be greatly discouraged. That recovery will take some little time there is no question, but that there will be recovery, and much more quickly than most of us think, there is not the slightest doubt in my mind. There is no class that can buckle down and work harder than the farmers. No industry that I have ever been connected with has the recuperative powers of agriculture. When it comes to getting back to normal, whatever that word may mean, I believe the agriculturist will be very nearly at the head of the procession, if not at the head.
>
> We are not suffering so much from a depression in agriculture as from the result of too much prosperity during the war period. The agricultural industry itself is all right. Some of those engaged in it are hurt but they will recover, or others will take their place. It is the same in manufacturing; somebody else will build tractors if we do not. I have never seen any satisfactory general business condition or situation except when the railroads were prosperous and in the market for their normal supplies.

THE ARGENTINE AND OTHER COMPETITORS

> In the Argentine, which is our principal competitor in grain production, the average rail-haul from all of the grain-producing sections to the ocean is less than 200 miles. The same thing is true of Uruguay and of Southern Brazil. A glance at the map of South Africa indicates that the haul is no greater there. The grain produced in the Upper Mississippi Valley, in Iowa, Minnesota, the Dakotas and parts of other States, must be carried to our Great Lakes ports, a distance that averages from 300 to 500 miles; and from the Lake ports it is 1500 miles to tidewater. We have maintained our place in the markets of the world, but the changed and changing conditions of transportation and handling will make it more and more difficult for us to compete if the present transportation rates continue.
>
> In the prewar period our freight rates were very

(*Concluded on page* 221)

Manifold Vaporization and Exhaust-Gas Temperatures

By O. C. Berry[1] and C. S. Kegerreis[2]

Annual Meeting Paper *Illustrated with* Photographs and Charts

STATING that present internal-combustion engine fuel is too low in volatility for economical use and that this is the cause of engine-maintenance troubles, the authors believe that, since it is not possible to obtain the more volatile grades in sufficient quantity, the only hope of remedying this condition is to learn how to use the heavy fuel, and that the most promising method of doing this lies in the effective use of heat.

As the experimental data regarding the best temperature at which to maintain the metal in a hot-spot manifold and the range of temperatures available in the exhaust gases, are meager, the authors experimented in the Purdue University laboratory to secure additional data. They present a summary of the results. They feel that the exhaust-gas temperatures are high enough so that properly designed manifolds, together with thermostatically controlled carbureter temperatures, should make possible the satisfactory carburetion of fuels considerably heavier than the present "power" gasoline, without seriously limiting the power, efficiency or flexibility of passenger-car engines or causing any engine-maintenance troubles.

THE present fuel situation is one calling for serious thought. Internal-combustion-engine fuel is so low in volatility that it is not being utilized economically. A large number of maintenance difficulties can be attributed to the low volatility of the fuel. The petroleum reserves cannot be increased and, even granting a liberal use of substitute fuels, we can scarcely expect the time to arrive when the refiner will be willing to return to a fuel of higher volatility. Therefore, our only hope of progress is to learn how to use the heavy fuel. A first-class solution of this problem might go so far as to make possible the use of still more of the heavy ends, enable us to get more out of each gallon of fuel and decrease the operating difficulties, thus constituting a real step in progress.

A considerable portion of our present grade of engine fuel passes through the intake-manifolds of automobile engines in liquid form. It is difficult to design a manifold that will distribute uniformly to all of the cylinders this liquid portion of the mixture furnished by the carbureter. No matter what condition the fuel is in when it reaches the cylinder, it must be vaporized before it can be burned. The most effective way yet found of improving distribution and combustion is to apply heat in some form or other. This makes it valuable to know how much heat to introduce and how to introduce it to get the best results.

One of the commonly used methods of heating the mixture is to have portions of the metal in the intake-manifold heated by the exhaust gases. The liquid fuel in the manifold tends to flow along the walls; therefore, it will come in contact with these hot portions and be flashed into a vapor. A considerable portion of the liquid is thrown out of the mixture at the carbureter throttle-valve and onto the walls immediately above the throttle. This liquid tends to cling to the walls. At very low air velocities, as when the engine is idling very slowly, it will often collect in a puddle immediately above the throttle, especially when the manifold has a long vertical section at that point. At higher air-velocities this liquid will rise through the vertical section of the manifold and collect at the bottom of the horizontal sections. The manifold is swept clean continuously of these liquid-fuel puddles only at comparatively high air-velocities. Still other portions of the liquid fuel tend to collect wherever the direction of the flow changes, or wherever there are eddy currents due to any other cause. Therefore, the ideal condition for drying the mixture would be to have the metal heated at these points, especially on the outside walls at the bends and at the vertical section just above the throttle. These heated portions of the intake-manifold are called "hot-spots."

It is claimed for this hot-spot method that it produces a mixture sufficiently dry without heating it as much as is necessary in the "heated-air" method. The ideal hot-spot manifold would accordingly be one that produced a mixture dry enough to distribute evenly and burn well in the cylinders, with the least possible heating of the mixture itself. Some hot-spot arrangements allow the whole mixture to come into contact with the hot metal, and consequently operate by heating the whole mixture. Others are arranged to keep the gases away from the hot metal as much as possible, while the liquid portions of the fuel are brought into contact with it and are vaporized. Such manifolds operate principally by heating the fuel itself after it has been metered.

The Society of Automotive Engineers appointed a special committee in 1919 to study the problems involved in the use of present internal-combustion-engine fuels. H. L. Horning served as chairman of this committee, and a careful study was made of the whole situation under his direction. The committee felt that the hot-spot manifold offered the most promising means of alleviating the difficulties encountered in carbureting the present engine fuels. Therefore, it made an exhaustive report on the present state of the art of designing hot-spot manifolds. This was presented to the Society and published in The Journal.[3]

In this report, however, as in the other literature on the subject, there is a lack of experimental data showing the optimum temperature at which to maintain the metal in the hot-spot, and the range of temperatures available in the exhaust gases of an engine under different running conditions. This information is fundamental in designing and perfecting any particular hot-spot manifold. Tests have therefore been carried out in the laboratories of Purdue University to obtain this informa-

[1]M.S.A.E.—Chief engineer, Wheeler-Schebler Carburetor Co., Indianapolis.

[2]Jun. S.A.E.—Assistant in carburetion research, Purdue University Engineering Experiment Station, Lafayette, Ind.

[3]See The Journal, July, 1920, p. 25.

tion. These tests were divided into two groups. The first deals with the optimum temperatures in the metal in the hot-spot; the second, with temperatures available in the exhaust gases, together with the factors influencing these temperatures. A complete report of these tests is contained in a bulletin published by the Purdue Engineering Experiment Station, entitled The Hot-Spot and Factors Affecting the Exhaust-Gas Temperatures. The present paper is presented through the courtesy of the Purdue Engineering Experiment Station and gives the general conclusions of the bulletin in an abbreviated form.

Hot-Plate Tests

Before a hot-spot manifold is designed for any fuel, it is well to determine the following three points:

(1) The rate of vaporization per unit of area for different temperatures
(2) The best temperature of the hot-spot for the vaporization of the fuel
(3) The cracking point of the fuel and the deposition of solid matter

This information will provide a foundation on which practical designs can be based for any hydrocarbon fuel.

Fig. 1 gives a general view of the apparatus used in the tests mentioned. An iron plate 5/8 in. thick, 4 in. wide and 8 in. long was placed over an electrical heating element and packed in a box filled with asbestos, at *A* in Fig. 1. A well *B*, 1.015 in. in diameter and 0.128 in. deep, was located at the top center of the plate. Two thermometer wells were drilled on each side of the plate, one of each pair being as close as possible to the vaporizing well and the others farther away to give the plate temperature at a point where there was little or no flow of heat. The heat was regulated by a salt-water rheostat, *C*, in series with the heating coil, ammeter and switch. The vaporized fuel was carried away through a hood over the plate connecting with an 8-in. vertical pipe. The gasoline was weighed on a small chemist's balance, the fuel being siphoned from a beaker on the scale through a small copper tube to a point 1/2 in. above the top of the well. This prevented any portion from touching the liquid or interfering with the vaporization. The flow of fuel was regulated by a needle-valve, placed in the line just outside of the hood. The temperatures were measured by 950 deg. fahr. nitrogen-filled mercurial thermometers, accurate to within 5 deg. at the extreme conditions. The time of each test was taken with a manually operated stop-watch.

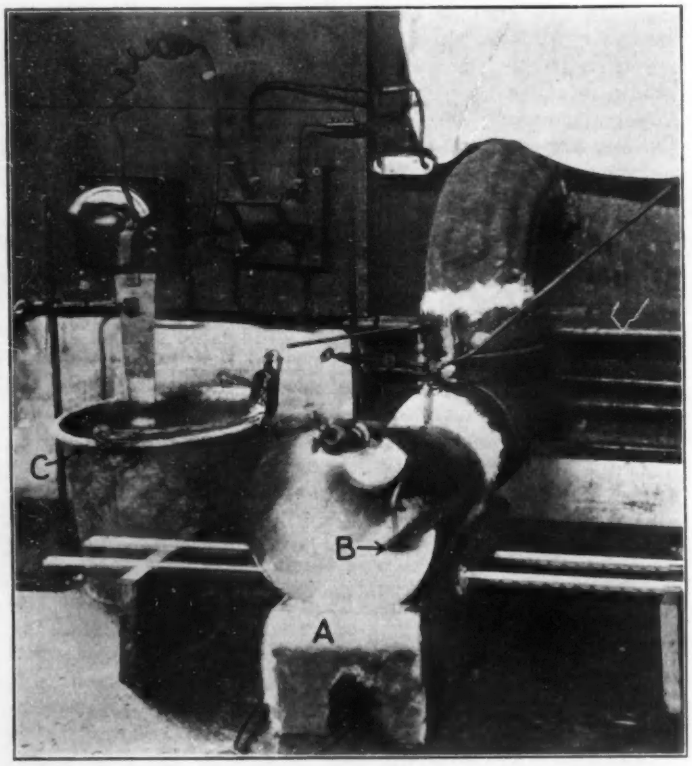


Fig. 1—General View of the Apparatus Used in Making the Tests

A portion of the fuel was thrown out over the edge when the first well, which was shallow, was used; consequently, too high a rate of vaporization per unit area was indicated. Therefore, in the later tests the vaporizing well was made deeper by welding additional metal around the top. When machined, this gave a well of 1.051-in. diameter and 0.610-in. depth. In this well too low a rate of vaporization was indicated. The reason for this is that the iron forming the upper part of the well was considerably farther away from the heating element than the thermometers and was consequently considerably below them in temperature. This resulted in a decreased vaporization from these upper portions. The entire wetted area was measured as the vaporizing surface; so the average rate of vaporization was lower than it would have been had the entire surface been at the temperature indicated by the thermometers. Since the results obtained from the first well tended to be too high, and those from the deeper well too low, an average between the two will represent nearly the real truth. In plotting the curves and reporting the results of these tests, the average figures are used.

The apparatus is liable to a few errors that can be eliminated by calibration. They are errors due to siphoning and the evaporation from the surface of the fuel in the beaker. The siphoning error is small and equal to the weight of gasoline displaced by the fuel-pipe between the initial and final levels of the fuel in the beaker, the pipe being considered as a solid. The error is 0.88 per cent for the individual beaker and pipe, and was corrected in the computation of the tests. The largest error is the evaporation from the surface of the fuel in the beaker. This is especially large for the lighter gasolines. This evaporation will vary according to the saturation of the air in the scale box. The temperature of the air above the beaker was recorded for each series of tests and from calibration tests this error was corrected with a considerable degree of accuracy.

Fuels Tested

One kerosene and three gasoline samples were tested. The specific gravity and distillation data are shown in Table 1. These fuels were obtained directly from a refinery through the courtesy of one of the leading manufacturers of petroleum fuels.

The distillation curve of a fuel is very valuable because the temperatures at which the fractions distill are the criteria by which comparisons of different fuels for volatility should be made. The specific gravity is a very uncertain indication of quality, because several combinations of petroleum fractions may have the same specific gravity and yet be wholly different fuels. The end-points and boiling temperatures of the fractions determine the character of the fuel more than the specific gravity.

The results of the tests are shown in Fig. 2, which gives the curve for each of the fuels tested. In these

TABLE 1—SPECIFIC GRAVITY AND DISTILLATION DATA OF FUELS TESTED

Percentage Distilled Off	Baumé Gravity of Fuel, deg.			
	70.0	64.2	56.5	41.5
Initial boiling point	97	120	96	346
10	127	155	162	386
20	143	169	210	400
30	155	179	247	408
40	165	187	272	413
50	176	196	295	424
60	187	205	313	432
70	193	215	335	440
80	206	227	356	452
90	225	245	381	476
Maximum	300	312	425	524

curves the temperature is plotted horizontally in fahrenheit degrees; vertically the time in minutes required to vaporize 0.01 lb. of fuel per sq. in. of hot surface is shown. The temperatures are in all cases those indicated by the thermometers nearest to the hot-spot in the hot plate. They represent 70.0-deg. high-test gasoline, 64.2-deg. domestic aviation gasoline, 56.5-deg. commercial power gasoline and 41.5-deg. kerosene, as shown on the Baumé scale. The curves are similar in general characteristics, the difference being that increasingly high temperatures are necessary to vaporize the less volatile fuels.

It was necessary to hold the temperature constant and continue the evaporation for a considerable length of time before each test was started. When the fresh gasoline was first introduced into the hot well, its rate of vaporization was rather high, the more volatile portions evaporating and leaving the heavier parts as a comparatively inert mass in the hot well. After a time, however, a state of equilibrium would be reached, when the fumes leaving the hot well would contain the same percentages of the lighter and heavier fractions as the original gasoline, and the proper rates of vaporization would be reported.

The fuel showed evidences of cracking during the period of rapid boiling, and a deposit of solid matter was left on the edges of the well. The two lighter gasolines, 70.0 and 64.2 deg. Baumé, left a deposit that resembled paraffin, while the deposit from the heavier gasoline and the kerosene had more the appearance of tar or carbon. When the liquid film was allowed to seep over the edge of the well these deposits were dissolved and carried out with the vapor. This vapor afterward redeposited some of the solid matter in the hood behind the well. When the spheroidal state was reached, the deposition of solid matter ceased entirely. This is very important to the designer of a hot-spot manifold. The temperatures that cause a deposition of solid matter are rather limited in extent and are entirely below those that will throw the fuel into the spheroidal state. The very high temperatures are not the ones that cause the clogging of the manifold.

The appearance of the vapor under different conditions was interesting. When the liquid was boiling from a wetted surface the vapor was very wet and condensed easily. In fact, its appearance as it was carried to the rear of the hood was that of a dense fog. In the spheroidal state, the vapor was dry and almost invisible; so that, even after it had traveled a few feet in a cool pipe, no appreciable condensation was noticed.

The curves in Fig. 2 show that the effectiveness of the hot-spot drops off very rapidly at the lower end of the temperature range. A similar curve for the fuel to be used will show the lowest temperature that it will pay to use with that fuel. It is not wise to attempt to make use of the highest rate of vaporization for two reasons. The temperature range is too narrow and this is where cracking and deposition of solid matter takes place. It is better to use the higher temperatures that produce the spheroidal state. After the spheroidal state is once reached, an increase in temperature does not make any very great change in the rate of vaporization. The metal in the hot plate was often red-hot during these tests, but at no time were the fumes from the hot-spot ignited by the plate when the latter was below 1425 deg. fahr. This makes it practicable to use a very wide range of temperatures in the metal of a hot-spot, and eliminates the necessity of using a thermostat.

Exhaust-Gas Temperature Tests

The second group of tests was intended to determine the exhaust-gas temperature of an automobile engine under different running conditions. Some very careful work had been done previously by several investigators to determine these temperatures under specific running conditions, but little attention had been given to the factors influencing them. The more important of these factors are as follows:

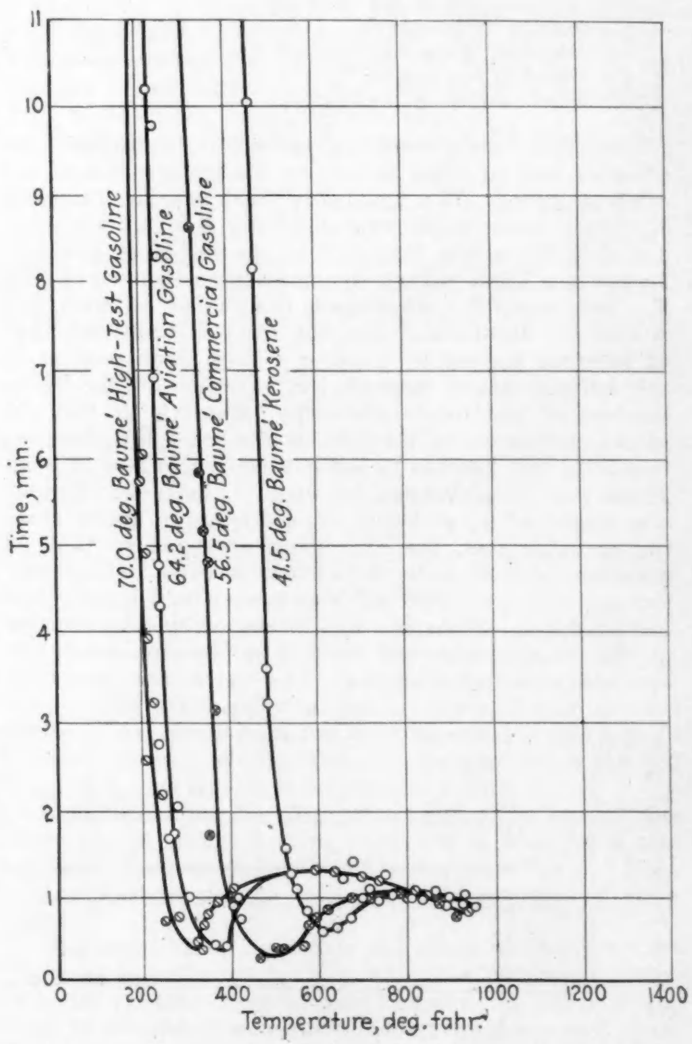


FIG. 2—CURVES GIVING RESULTS OF FUEL TESTS ON KEROSENE AND THREE GRADES OF GASOLINE

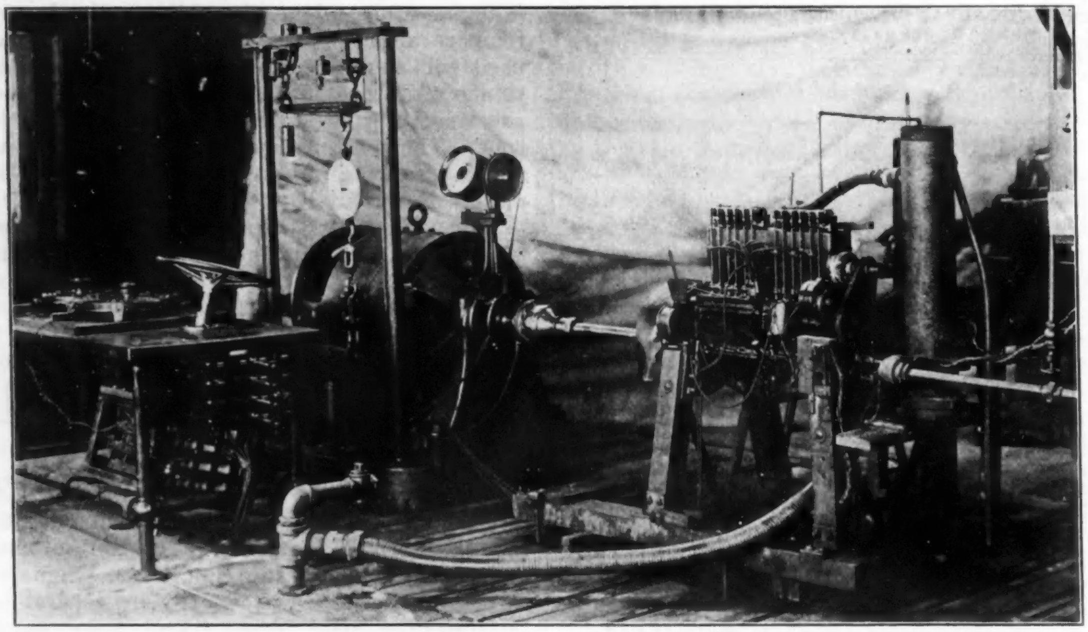


FIG. 3—THE SIX-CYLINDER ENGINE USED IN MAKING THE TESTS WAS MOUNTED ON A TEST-BLOCK AND CONNECTED TO AN ELECTRIC DYNAMOMETER

(1) Temperature of the cooling water
(2) Temperature of the inlet air
(3) Timing of the spark
(4) Richness of the fuel mixture
(5) Speed of the engine
(6) Load carried by the engine

Therefore, tests were carried out to determine the effect of each of these factors on the temperature of the exhaust gases. The apparatus used was an Oakland-Northway six-cylinder engine having a 2 13/16-in. bore and a 4¾-in. stroke, mounted on the test-block and connected to a Diehl electric dynamometer as shown in Fig. 3. Two manifolds were used, designated as manifolds *A* and *B*. Manifold *A* had the early conventional type of hot-spot formed by passing a very small portion of the exhaust gases around the exterior of the three headers of the intake-manifold. Manifold *B* had the intake cast on top of the exhaust and enough contact between the two headers to cause considerable flow of heat. These were interchanged for some of the tests. The air was measured by an Emco No. 4 diaphragm meter reading to cubic feet, the dial being arranged so that an accurate estimation to tenths was possible. The gasoline was siphoned from a 2-liter beaker on a large chemist's balance. The speed was measured by a tachometer on the dynamometer and verified by the stop-watch and revolution-counter readings. The watch, the revolution

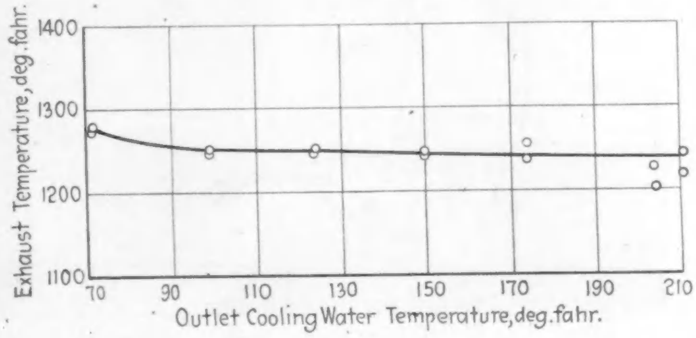


FIG. 4—THE EFFECT OF THE TEMPERATURE OF THE COOLING WATER ON THE EXHAUST TEMPERATURE IS RATHER SMALL

counter and the air meter were electrically controlled by the scales, to start and stop the measurement of these quantities at the same instant. The air was heated to any temperature desired by a gas-heater that could be regulated by controlling the gas-burners. All temperatures, such as those of the inlet air, and the cooling water, and all the hygrometer readings, were measured with mercurial thermometers; the exhaust-gas temperatures were measured with iron-constantin thermocouples,

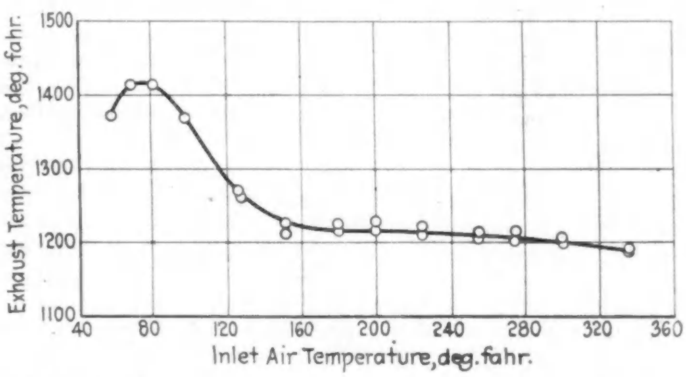


FIG. 5—CURVE SHOWING THE EFFECT OF CHANGING THE TEMPERATURE OF THE AIR ENTERING THE CARBURETER

and these were calibrated carefully. These thermocouples were placed near the outlet end of the exhaust manifold. The manifold was drilled and the couples allowed to extend a little more than half-way through the passageway. The couples were not covered, thus allowing the gases to come directly in contact with them, and the point where they entered the manifold was packed with asbestos, to prevent them from being cooled by the manifold walls. The temperatures reported, therefore, represent the actual temperature of the gases at the point where they would be most likely to be used in producing a hot-spot.

The tests to show the effects on the exhaust temperature of the temperature of the cooling water and of the inlet air, the timing of the ignition and the richness of the fuel mixture were all run at one-half load at an en-

gine speed of 1000 r.p.m., holding all of the running conditions constant except the one to be tested. The engine was allowed to run under test conditions for a considerable length of time until all of the temperatures had come to an equilibrium before each test was started.

The temperature of the cooling water was varied between 70 and 212 deg. fahr., the tests being run at one-half load, at 1000 r.p.m. The results are represented graphically by the curve in Fig. 4. Contrary to what might be expected, the effect is shown to be rather small,

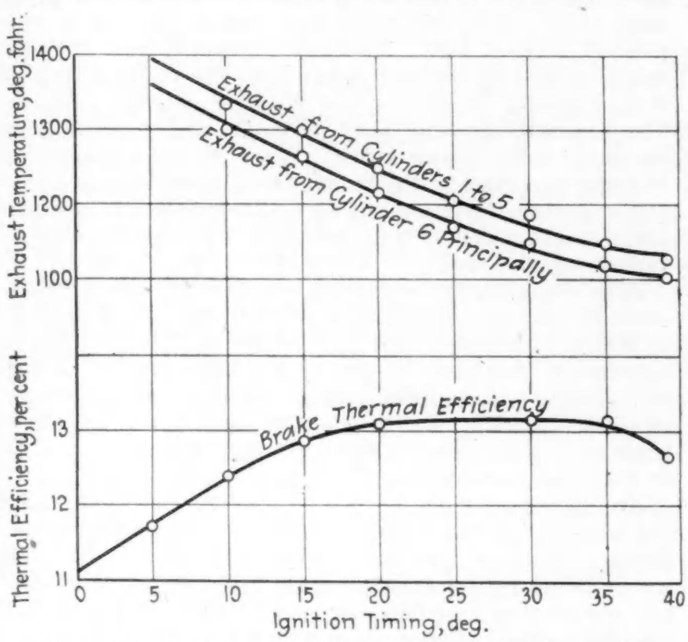


Fig. 6—The Effect of Changing the Spark-Timing on the Exhaust Temperature and the Brake Thermal Efficiency

and heating the engine produces a slightly lower exhaust-gas temperature.

Two series of tests at one-half load, at 1000 r.p.m., were run to determine the effect of changing the inlet-air temperature, this being varied between 59 and 335 deg. fahr. The results are shown in Fig. 5. The peculiar shape of the curve can possibly be explained by saying that the 59-deg. air probably did not enable the engine to burn all of the fuel. As the temperature increased to about 80 deg. fahr., the combustion became complete and, since it was so very slow, the loss of temperature due to radiation and work were at a minimum and the exhaust-gas temperatures were at a maximum. During the period between 80 and 160 deg. fahr. the vaporization of the fuel improved very rapidly, the combustion became more and more rapid until it was complete at the begin-

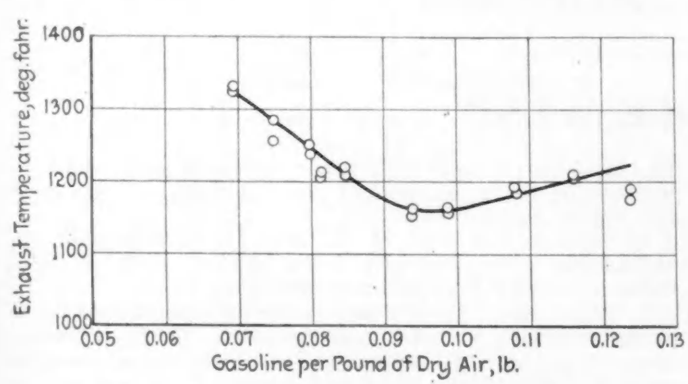


Fig. 7—How Changes in the Fuel-Air Ratio Affect the Exhaust Temperature

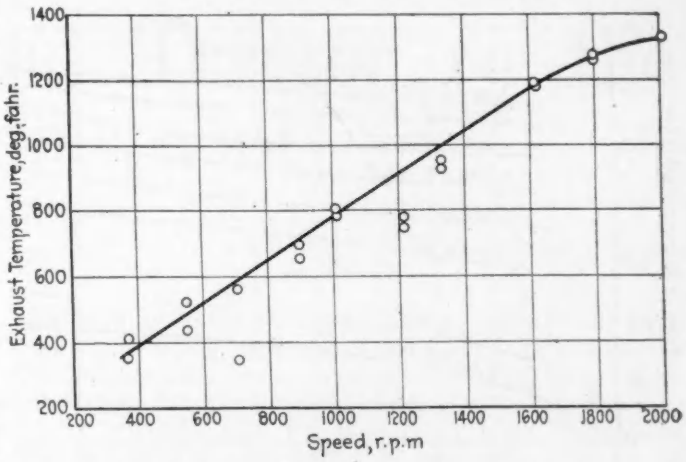


Fig. 8—Relation Between Changes in Speed at Low Load and the Exhaust-Gas Temperature

ning of the working stroke, the loss of temperature due to radiation and useful work reached a maximum, and the heat left in the gases at the time they were exhausted from the cylinder decreased rapidly. The decrease in the exhaust temperature above an inlet temperature of 160 deg. fahr. was not so pronounced, since an increase in the rate of combustion beyond the point where it was complete before the beginning of the working stroke could not have very much effect.

The effect of changing the spark-timing was studied with the engine running at one-half load, at 1000 r.p.m. The tests showed that advancing the spark reduced the exhaust temperature, but that the effect is not large. Fig. 6 shows the results graphically.

The effect of changing the fuel-air ratio was checked

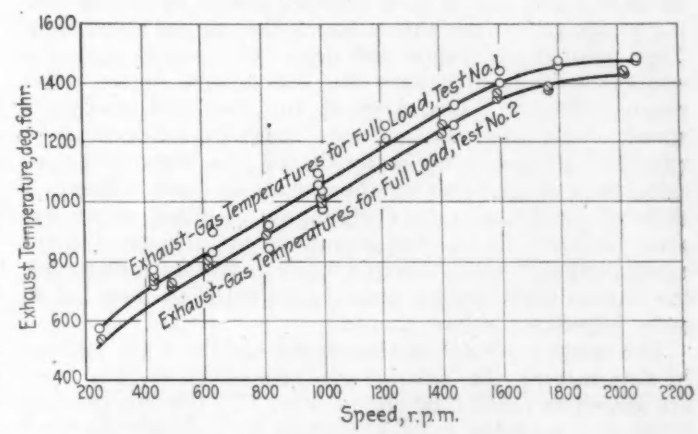


Fig. 9—Relation Between Changes in the Speed at Full Load and the Exhaust Temperature

by running three series of tests at one-half load, at 1000 r.p.m. Two series were run with manifold *A* and a third series with manifold *B*. The tests on manifold *A* checked very well, the results being shown in Fig. 7.

In determining the effect of changing the speed, tests were run at speeds varying from 300 to 2000 r.p.m. and at light, one-half and full load, using manifold *B*. Figs. 8 and 9 show results that are characteristic of these tests.

The speed tests also show the effect of changing the load, as is indicated by Fig. 10. The maximum difference in exhaust temperatures between no load and full load is 270 deg. fahr., which occurs at the lowest speed used in these tests, namely, 300 r.p.m. As the speed in-

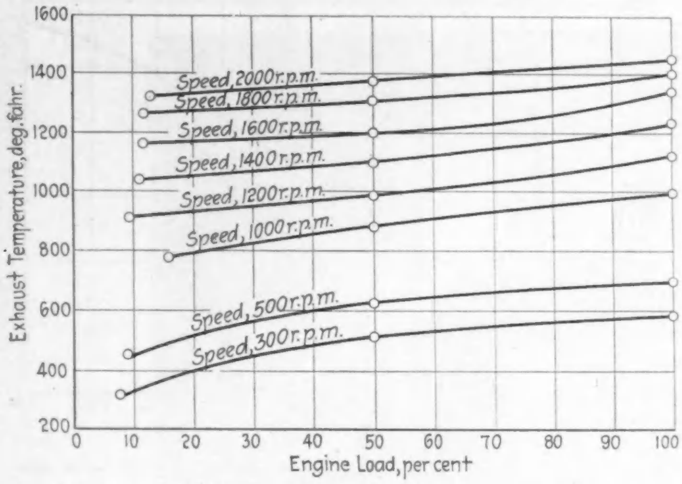


FIG. 10—RELATION BETWEEN THE ENGINE LOAD AND THE EXHAUST TEMPERATURE AT DIFFERENT SPEEDS

creased, this difference decreased until, at 2000 r.p.m., it was only 110 deg. fahr.

The maximum exhaust temperature obtained at 2000 r.p.m. was 1460 deg. fahr., under full load, with a 31-deg. spark advance, a mixture temperature of 220 deg. fahr. and a mixture ratio of 0.08 lb. of gasoline per lb. of dry air. A special test was made at 300 r.p.m. with all of the conditions adjusted to produce the lowest possible temperature. It was possible to get down to 300 deg. fahr. under these conditions. It is obvious that the main factor in determining the exhaust temperatures is the speed at which the engine is running.

DISCUSSION OF RESULTS

The tests show that the temperature of the exhaust gases from an engine vary through a wide range, according to the conditions under which the engine is running. They seldom get below 300 deg. fahr., even when the engine is idling at a very low speed, and do not often reach 1500 deg. fahr., even at full load and maximum speed. The lower end of this range is too low to be effective in vaporizing many of the fractions of petroleum that are offered to the public as fuel. There is little choice left to the designer or operator of an engine, however, as to what he can do to influence the exhaust temperatures. Nearly all of the factors influencing the engine performance must be adjusted to meet other more important requirements.

The speed and load of the engine are the main factors in determining the exhaust-gas temperatures, but they are governed usually by the service. To prevent getting below any specified exhaust-temperature, it will be best to operate the engine under conditions that will result in good performance and maximum power and efficiency, but to plan to stay above the special speeds and loads that are shown to be necessary in producing the desired temperature. The speed is more important than the load; so the principal requirement will be to stay above some specified speed.

An effort should be made to heat the fuel without heating the air in the manifold itself. There are two main reasons for this. The fuel can thus be vaporized at a very high temperature without the use of a great amount of heat, and this vaporization can be accomplished very rapidly. The dry fuel-vapor can then be mixed with cool air and drawn into the cylinder before it has time to condense and drop out of the mixture. The final mixture can thus be made usably dry at the lowest possible temperature. When the air is allowed to come in contact with the hot-spot, it becomes unnecessarily heated itself and tends to keep the metal in the hot-spot at too low a temperature to be most effective in vaporizing the fuel.

After completing this work, we feel that the greatest cause of the poor carburetion of our present engine-fuel is due to improper manifold design and that a great opportunity for progress lies in the improvement of the manifolding of engines. The advance will be made through learning how to use the heat in the exhaust gases and in introducing this heat into the intake charge in the proper amount and in the best way.

An important element in this problem, but one that lies outside of the scope of this paper, is the thermostatic control of carbureter temperatures. There is enough heat in the exhaust gases and the temperatures are high enough so that properly designed manifolds, together with thermostatically controlled carbureter temperatures, should make possible the satisfactory carburetion of fuels considerably heavier than our present "power" gasoline, without seriously limiting the power, efficiency or flexibility of passenger cars or resulting in any of the difficulties that are now due to poor manifolding systems. By a small increase in the minimum engine speed, still heavier fuels can be used. A careful study of how to use the exhaust heat best should therefore prove a great benefit to the whole motoring public, and a real step in the direction of progress. The manufacturers of the cars that are already built should take this fact seriously and provide not only for their future models but also produce improved manifolds that can be installed on their older cars, thus improving the quality of their service and prolonging their years of usefulness. It is our hope that the information we have assembled will prove of assistance to those in the industry who are striving to accomplish these results that are greatly to be desired.

THE MIDDLE WEST

FROM an agricultural standpoint the Middle West produces an abundance far beyond its own consuming power. With but little more than 50 per cent of the population of the United States and not more than 5 per cent of the world's population, this region produces approximately 20 per cent of all of the wheat grown throughout the entire world and 60 per cent of the world's corn crop.

In addition to producing these two essential food products, this portion of the United States is an important source for basic materials and a great manufacturing center. Here is produced over 30 per cent of the world's supply of bituminous coal, 37.6 per cent of the world's iron and steel, 42.0 per cent of the world's cotton, and 45.0 per cent of the world's oil. So far as transportation facilities are concerned, this region stands pre-eminent.

At least 44 per cent of the total manufactures of the United States are produced in this region. This, however, is but a fraction of its potential producing ability.

In 1920, the United States exported $4,163,354,637 of partly or wholly manufactured products. This represented about 50 per cent of the Country's total exports of domestic products. The Middle West contributed 44 per cent of this total, or $1,842,284,426.—W. F. Gephart in *The Economic World*.

The Relation of the Tractor to the Farm Implement

By G. Douglas Jones[1]

Minneapolis Tractor Meeting Paper

STATING that the trend of tractor development must be toward the small tractor that is capable of handling all of the power work on a farm, the author quotes farm and crop-acreage statistics and outlines diversified farming requirements, inclusive of row-crop cultivation.

Tractor requirements are stated to be for a sturdy compact design to meet the demands of the diversified farm, which include plowing, seeding, cultivating, hauling and belt-power usage, and these requirements are commented upon in general terms. Consideration is given to farm implements in connection with tractor operation, and the placing of cultivating implements ahead of the tractor is advocated.

FARM tractors have been in general use for more than a decade, but the industry finds itself still in the development stage. Its future will depend largely upon the ability of the tractor manufacturer to satisfy the farmer by providing both a power unit and suitable farm implements to accompany it that will accomplish his farm work without requiring any radical change in working methods. Therefore, the trend of development must be toward the small tractor that is capable of handling all of the power work on a farm, because the volume of sales must come from the smaller farms, which are in the majority by 4 to 1. These farms comprise an area of from 50 to 200 acres. The number of farms of this size in the United States is in excess of 4,000,000, while farms of greater acreage number slightly in excess of 1,000,000. The tendency of to-day is to reduce the acreage of the larger farms.

The average size of farm in the corn belt is approximately 100 acres. The same is true in the South. Even in Texas the records show the average to be approximately 125 acres. In the East farms average 100 acres. Thus the large acreage practically is confined to the inland empire. A simple method of illustrating farm volume is by the use of a pyramid. Let a section near the apex represent the large individual acreage with small tractor volume; let a section near the middle represent all individual acreage above 200 and below 1000 acres; and let the base section represent the farms of less than 200 acres. This base section represents the diversified crop area.

Diversified-Farming Requirements

A farmer raising diversified crops must, of necessity, own and use a great many types of implement to carry on his farming successfully. A typical list of this farmer's implement requirements includes a plow, a disc harrow, a springtooth harrow, a drag harrow, a corn planter, a corn cultivator, a corn harvester, a wagon, a mower, and, in the majority of instances, a grain binder. In addition, the farmer has belt-driven units, which range from a circular saw to a threshing machine. A large investment is represented by these implements that are necessary to carry on his work successfully. All of them have been horse-drawn heretofore. They must be adapted to the tractor or the tractor must be adapted to them, before the farmer can get complete power-farming service.

The unusually high prices paid for farm products in 1919 and early in 1920 led the farmer to buy tractors indiscriminately. When prices again became normal many of these farmers found that their power equipment could not produce the crops at a profit on the basis of the new and lower market prices. This situation makes it doubly necessary that the tractor industry produce both tractors and implements that will compete effectually with the cost of raising farm crops by animal power. The problem before us is to meet this diversified farmer's requirements as completely as possible without interfering too severely with his present working methods. In considering the crops raised by him, the paramount obstacle has been his inability to handle intertillage work; that is, to cultivate his row crops.

Row-Crop Cultivation

Although corn is grown on more than 102,075,000 acres in the United States, other row crops that must be considered include potatoes, with an average acreage of more than 4,000,000; cotton, covering an acreage in excess of 35,000,000; beans, which exceed 1,000,000 acres; peanuts, in excess of 1,000,000 acres and steadily increasing; and sugar beets, which average 1,000,000 acres and show a rapidly increasing acreage. There are many more important row-crops that cover smaller acreages, such as tobacco and truck crops, inclusive of cabbage, onions and tomatoes. They cover an acreage in excess of 2,000,000. Thus, we have approximately 146,075,000 acres of row crops in the United States, and practically all of this acreage is located on the smaller or diversified farms, where crop rotation plays an important part.

Tractor Requirements

A tractor must be of sturdy and compact design to meet the demands of the diversified farm; yet it must be so simple that it can be operated easily after the briefest period of instruction. The accessibility of its working parts is just as important so that repairs can be made with minimum of delay and without the necessity of summoning an expert mechanic. Lubrication and greasing should be confined to no more than two points, so that the day's work in the field need not be cut short by tedious delays to attend to this rather vexing but all-important duty. This type of tractor, which appeals because of its cheapness of maintenance and simplicity of operation, must be adaptable to the farmer's manifold needs and to the implements that he already possesses. It is essential that he be not overburdened with the cost of purchasing new implements to effect this much-desired result.

Of the many tasks that fall to the diversified farmer, plowing is foremost of all. He must be able to plow

[1] M.S.A.E.—Agricultural engineer, Cleveland Tractor Co., Cleveland.

from 6 to 10 acres in a 10-hr. day with a two-bottom gangplow of the disc or the moldboard type. He must be able to travel at such speed as to pulverize for seed bedding the particular type of soil that predominates on his farm, eliminating the work of harrowing so far as possible. This requires a variety of speeds, for sandy soil demands far different treatment than clay or loam.

The new type of tractor must be able to exert adequate drawbar pull and at the same time be light enough to drag the harrow over the tilled field without packing the soil too firmly and retarding the germination of the budding seed. To accomplish this, the tractor must be able to pull a double-disc harrow, a spring-tooth harrow and a drag harrow, of such size and at such a rate of speed as to complete from 20 to 30 acres in a 10-hr. day. Tractor lightness is necessary also to permit the seeding machine to be hauled over the ground and yet leave the seed-bed in such a state of tilth that rapid germination of the seed will follow without the ill effects due to tramping or mashing the soil.

The tractor must be able to handle the long list of haulage jobs that are necessary on these farms throughout the year. It is evident how numerous these are, and what a variety of demands they entail. Cultivation of the soil is just as important as plowing in connection with the successful growth of row crops. In the past this work has been done by animal power or by special units primarily designed for cultivating. It is not necessary to have a specially designed powerplant unit that is used only during 6 to 8 weeks throughout the year, because all the essentials of this unit can be incorporated into the ideal tractor so that it can be used as expeditiously for cultivating as for any other farm work. Thorough cultivation is necessary; not a system of cultivation that covers the ground in the quickest manner possible, but a system that will bring about far better results than ever have been accomplished by handpower or animal power in the past. The problem is not a difficult one. It can be solved by tractor methods simply and easily if thought and effort are devoted to it. The ideal tractor must, of necessity, handle the numerous belt-power jobs on the farm, such as furnishing power for the feed mill, the wood saw, the corn shredder, the ensilage cutter, odd demands, the small cream-separator and the threshing machine. This problem of belt work has been and is being handled very satisfactorily by all tractors built today.

The requirements for a simple tractor for the diversified farmer demand a small compact sturdy machine of sufficient flexibility and ease of manipulation to handle all of the numerous tasks better, more cheaply and expeditiously than they have been handled in the past. Radical changes are needed. We still are holding to the cumbersome design of pioneer tractor that broke the virgin sod; one that caused endless delay through innumerable troubles and was designed primarily as a plowing unit. We must evolve a small design to meet the requirements of the farmer of today. This must be borne in mind constantly so that present-day implements will be available for use with the tractor. While making it rangy, the design must be kept simple, so that the tractor can be widened or narrowed and raised or lowered to give clearance, without the addition of complicated parts that require time and expense in the making of alterations.

Implement Requirements

Unobstructed vision for the operator is a prime requisite in the successful manipulation of cultivating implements. This can be accomplished most feasibly by placing the implements before the tractor, the driver being enabled thereby not only to manipulate the machine but to watch the progress of the work and note any emergency that arises. The working force can be cut in half in this manner. When the implement is drawn behind the tractor, a helper is necessary to manipulate it.

ORGANIZATION BY FARMERS

OUR Nation was established by one-man enterprise; the one-man farm whose products fed and clothed the family, the one-man store, the one-man blacksmith shop, the one-man stage coach, the one-man mail service. What distinguishes the Nation today is the fruit of associated, or organized, effort. Transportation, communication, manufacture, merchandising, are all conducted by great groups, often thousands of individuals, each with its leadership of superior ability, a leadership which has been earned by the survival of the fittest in years of competition.

Because every farm is a home, it is not likely to become factory organized; but agriculture, like other industries, has come to a time when all its problems cannot be solved by the farmer acting as an individual. Farmers must associate in groups. They must acquire the assistance and benefits of associated effort under skilled leadership. Successful leadership is the result of accumulated experience. The permanence and effectiveness of associated groups in agricultural efforts depends upon the development of successful leaders, able to read all factors aright, to think rightly and to decide rightly, to the end that all groups may prosper better because of the proper kind of leadership and the associated effort of many individuals acting in harmony.—President Van Norman of World's Dairy Congress Association.

THE BASIC INDUSTRY

WE frequently think of the iron and steel industry or some other industry with which we are most familiar as being the greatest and most important of the industries of the country upon which the prosperity of business mainly depends. But after all, the present business depression has shown that the country's prosperity depends largely on the buying power of the farmer. Nearly one-third of the people of the United States, or more than 30,000,000, live on farms. Nearly 20,000,000 live in communities having a population of less than 2500 and depend for their well-being mainly upon the prosperity of the farmer. In other words, nearly one-half of the population of the United States is directly dependent upon the farms for its income and its purchasing power. When this large part of the population begins to curtail its purchases to a minimum, as has been the case since the fall in the prices of farm products, every industry in the country suffers. In 1919 the value of the farm property in the United States was estimated at more than $50,000,000,000 or more than the combined capital of all the manufacturing establishments, railroads, mines and quarries in the country. The value of the output of the farms at prewar prices is estimated at $8,000,000,000.—*Machinery*.

Commercial-Body Supply and Service

By C. M. Manly[1] and C. B. Veal[1]

Chicago Service Meeting Paper *Illustrated with* Photographs

SPECIFYING the four general plans that have been followed by chassis builders in securing body equipment as being the building of bodies in their own shops; on contract by the body maker to plans and specifications of the chassis builder; by a local body maker to the order of the dealer or the owner; and the assembling from stock of standard sectional units recommended by the dealer or selected by the owner, the authors discuss each of these plans in detail.

With regard to the plan of using standardized sectional bodies, the different sizes of chassis used for commercial purposes are separated into four specified groups and the production of a complete standard line including a number of styles of body for each chassis is commented upon and illustrated, inclusive of detailed considerations of the all-metal body. The advantages to the dealer and to the user of the factors that are advocated in body building are enumerated, and the standardization of commercial cars and trucks is considered briefly.

SERVICE, in its broadest sense, must cover every phase of the marketing and operation of commercial motor vehicles and trucks. Whatever success is attained in the industry must be based fundamentally on *service*. Service to the dealer, good or bad, begins directly when the chassis is assembled, and continues through him, or directly to the consumer, throughout the usable life of the vehicle. The best interests of the dealer demand a service that results in the largest volume of sales, quickly made, with the minimum capital investment, and at the same time insures that greatest of all selling assets, *satisfied customers*.

The commercial car and truck chassis builder turns out, for the most part, a product that can be rendered useful only by the application of a body. Therefore, he should be vitally interested in having the final user of his vehicle obtain a body of good quality, properly mounted and adapted to the chassis and the work to be done. He is likewise concerned with everything that helps his dealers. The consumer, in this case the truck owner and operator, deserves to receive promptly, with a newly purchased chassis, a body suited to his needs with the assurance that it is durable and can be repaired with a minimum of delay and lost time for the vehicle.

The whole fabric of body service must be woven around the idea that a commercial motor vehicle has rendered its maximum of profit and usefulness only when the paying operation begins as soon as possible after it is assembled and continues steadily at a maximum per diem for the longest time with minimum losses through lay-ups for repairs and renewals. Any attempt to analyze the question of body service, therefore, must bring into consideration all phases of body design, production and distribution, as related to the chassis manufacturer, the dealer and the owner, as well as the body manufacturer, or builder.

Four distinct general plans have been followed by chassis builders in securing body equipment:

(1) Building in their own shop
(2) Building on contract by body maker to plans and specifications of chassis builder
(3) Building by local body maker to order of dealer or owner
(4) Assembling from stock standard sectional units recommended by dealer or selected by owner

All four are available, to a greater or less extent, at present and to determine the effect of each upon the ultimate question of service we will examine each plan as related to the interests of the chassis builder, the dealer and the owner.

Chassis Builder Constructing Bodies

The chassis producer who attempts to enter the body-building all-metal bodies is contemplated. Even then the chassis with bodies, will find it necessary to make large investments in plant and equipment, as well as provide an entirely separate organization for their design and manufacture, since body-building is essentially a wood-working industry, as contrasted with the metal-working operations of chassis construction, unless the questionable procedure, treated more specifically later, of building all-matel bodies is contemplated. Even then the type of metal work involved is entirely different from that of chassis construction, and requires radically dissimilar shop and tool equipment and personnel. Many of the large sheet-metal workers have been kept out of the body business because sufficient quantities of bodies of uniform type and dimensions cannot be sold to make the tooling and other quantity-production worthwhile. The fact that some of these companies turned out truck bodies efficiently and at a low price for the Government in war time but have since found it unprofitable to produce for the trade under present conditions of standardization, or, rather, lack of standardization, should make clear to the chassis builder the inadvisability of going into the construction of metal bodies where the outlet for these bodies must necessarily be limited by the sales of their own chassis.

If the chassis builder plans anything like national distribution of his product, he must offer a line of bodies sufficient to meet the widely varying demand in different sections of the Country. To satisfy the requirements of Northern winters the driver must be protected from the cold with a complete enclosed job, while in California and the Southwest, in fact, all through the South, there is no market for such body types. In addition to these climatic considerations, every section of the Country insists upon certain features peculiar to itself, either because of more or less clearly defined limitations of the prevailing business in which the body is employed, or through unnecessary but obstinate adherence to established local custom.

Even if local distribution only is attempted, a considerable variety in types must be offered, for not only must "the butcher, the baker and the candlestick maker" be provided for, but the grocer, the department store, the

[1] M.S.A.E.—Consulting engineer, New York City.

manufacturer, the farmer, and, in fact, every conceivable business and trade, comes in for special attention in developing any adequate line of bodies.

A large proportion of the city demand will be for panel bodies, if for no better reason, because the large, plain panels of the sides have a real value for advertising purposes. In sparsely settled districts advertising space is of less value and consequently the small town and country merchant and tradesman will purchase only an express-type body, with or without top. The farmer generally has little use for the commercial body type that is most popular in the cities, and demands an entirely different design, depending in detail upon the particular branch of agriculture in which he is engaged. In the wheat belt his body must be grain-tight and preferably fitted with a special grain endgate and other features peculiarly suited to his needs. If he is raising cattle or hogs, he will probably want a stock body, and if this body can be equipped with a stock-loading chute, its sale will be made easier. While the general all-around farmer will prefer some form of universal, convertible platform-type of body, the dairy farmer will demand something different, the orchardist something else, and so on; each prospective purchaser will insist upon some type as being suited to his need. No scheme of body service will be satisfactory to these various consumers, or promote the best interests of the industry, that does not take seriously into account all the conditions leading up to their individual demands.

There are many groups of merchants that require more highly specialized bodies, such as ice-cream manufacturers, furniture dealers, florists and undertakers. Then there is a large class of users of dump-bodies or other bodies with special loading or unloading devices, including contractors and dealers in coal, lumber, sand, gravel, brick, cement and other builders' supplies.

The larger department-stores are representative of an extensive class of buyers who have created an unmistakable advertising value through years of use of bodies of distinctive, uniform design, painting and attractive appearance. For purely economic reasons, such users can ill afford to purchase bodies of varying type, even though the saving in first cost may be considerable.

Frequently peculiarities, not always evident to the outsider, in the transportation problems of a particular company fully justify the employment of highly specialized bodies, through savings actually effected thereby. In contrast with these cases, it is true that there is a large class of users, who, so far as efficient handling of their goods is concerned, could use a common type of body but, to gratify their personal preferences or pride or idiosyncrasies, insist upon exceptional construction and are willing to pay a higher price to obtain a body changed or built to suit them.

In the final analysis the chassis builder can find no better reason for entering the body-building field than that of increasing the sale of his chassis. A serious consideration of the widely varied types of body required to meet the demands of his market cannot but convince him that the investment and expense involved will be out of all proportion to the increased profit on his product if he attempts to cater to all prospective customers. On the other hand, limitation of the body types offered with his chassis to a very few standardized jobs, combined with insistence on selling the chassis and mounted body as a unit, is certain to result not only in small body sales but in reduced sales of chassis, since a large proportion of buyers will not take kindly to having a so-called standardized body forced upon them regardless of its suitability for their service. Under such circumstances the loss will be greater than any possible gain, since the customer will buy the chassis that gives him a free hand in obtaining the body best suited to his needs.

Commercial motor-vehicle bodies are too bulky to be shipped long distances economically by rail and, excepting the limited number of vehicles that can be driven away from the factory, the mounting of bodies at the builder's plant need not be considered as having any great possibilities.

One of the great obstacles in the way of chassis and body standardizaton has been the bulkiness of bodies in railroad freight transportation, the possibility of damage in shipment and the expense of crating. The prohibitive expense of shipping complete bodies "set-up" can be somewhat reduced by shipping them to dealers "knocked-down," thus increasing the number of bodies which may be placed in a 40-ft. freight-car from 6 to 16, and throwing the burden of assembly and mounting on the dealer.

In any case the dealer's capital requirements will be increased by having bodies added to the inventory that he must carry. If the line of bodies he has to offer is sufficient to meet the demand, the expense of storage space becomes no small item, while a limited line cannot meet competition and results in loss of sales through inability to assure proper body service to prospective chassis purchasers. It is generally accepted that the dealer in commercial cars and trucks can succeed only by selling transportation rather than simply vehicles and he cannot claim to sell transportation unless he is prepared to recommend the body types best adapted to the purchaser's needs. The whole process becomes still more expensive for the dealer if he must furnish the facilities and labor for assembling and mounting bodies.

If the chassis builder takes a compromise course and offers a medium number of well-selected types, of which the dealer carries a small stock continually, the most promising purchaser is likely to be disgruntled because the body service offered with the chassis is not all that he expects, or can obtain elsewhere, so far as variety is concerned. Even if he does not go elsewhere to buy at first, the dealer is certain to find it burdensome to carry parts and be prepared to make repairs on the limited number of each type going out on sales of complete units. As anything less than a maximum of service in repairing and remodeling bodies will prove unsatisfactory eventually to the user, the effort expended in trying to build up a permanent business of selling the chassis and the body as a unit is, with few exceptions, certain to be entirely out of proportion to the results attained.

Bodies Built According to Specification

The second plan, while it necessitates the chassis builder carrying a body-designing and engineering department, relieves him of the greater investment in shop and tool equipment and body fabricating organization. The body builder, through his ability to furnish other designs of his own for the trade and to take on contracts to supply various chassis producers, is in a much better position than the latter to acquire an adequate volume of body business for efficient and economical production. Here the advantage to all concerned, as compared with the first plan, ceases, however, since the distribution troubles remain the same, with the possible addition of an initial freight shipment of bodies from the body builder to the chassis plant, and the complications arising in repair service with the attendant embarrassment to the ultimate user through the interdependence of the chassis producer and the body builder in all matters of

responsibility affecting the guarantee, proper functioning and durability of the body. Of the four methods applicable to the supply of bodies for commercial vehicles and trucks having national distribution under existing conditions, undoubtedly this plan has the least to recommend it.

Custom-Built Bodies

The third plan, historically, has been the accepted method of most motor-vehicle builders upon first entering the commercial-car field, and is still the plan generally followed by the majority of truck companies. This practice came into effect not through the application of any special economic theory but rather through the natural working-out of conditions as they were and still are to a lamentable degree, especially in connection with heavy-duty trucks.

Comparatively few automobiles were used for commercial purposes until within the last ten years, and even as late as 1913 the bodies necessary for these few commercial chassis were built principally by small wagon-shops for the owner or furnished to him by the chassis builder. Where the body problem is put up to the dealer and he endeavors to answer it through the medium of the custom builder, he may expect bodies only slightly developed from those for horse-drawn wagons, in the production of which custom builders have, for the most part, obtained their experience. The result is a body of much greater weight than is necessary from an engineering standpoint, and built, rather than designed, without regard for the principles involved. Progress in the art of custom body-building for commercial transportation has been almost negligible, all alike having followed horse tradition. Nor is progress to be expected from the local body-builder, hampered as he is by tradition and lack of technical training; he cannot advance even if he desires to advance.

With the exception of dealers in vehicles of exceptionally high quality, the dealer is forced by competition to obtain a fairly good body at a medium price. The methods and equipment of the local builder are usually very crude. He generally has little or no modern woodworking machinery and must depend upon tedious hand-

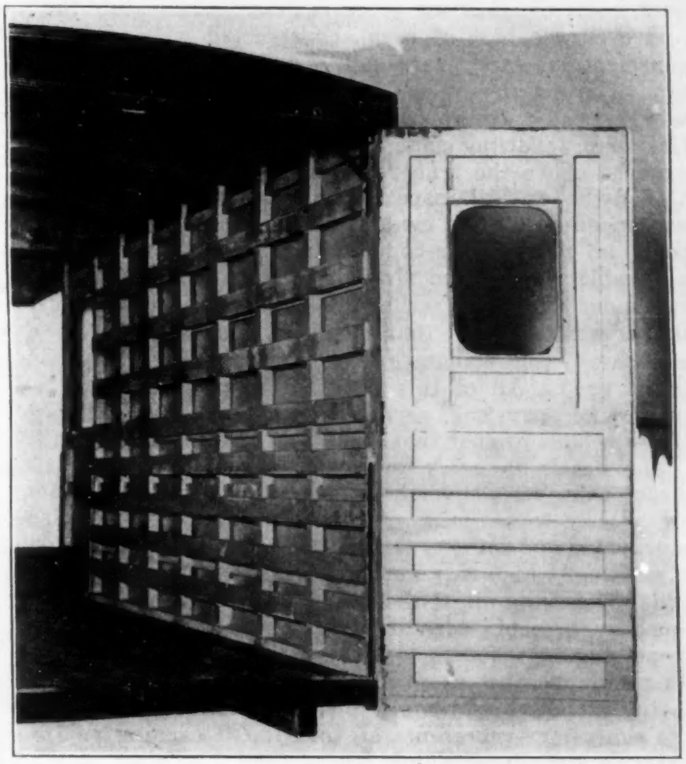


Fig. 2—Interior of Partially Assembled Panel Body and Rear Door

work for all or most of the fitted parts. Through hurry, carelessness, or improper supervision, poor workmanship results. Such bodies, loosely fitted together, soon become wobbly, decay sets in prematurely from moisture getting into the joints and the life of the body is wofully reduced.

The dealer who expects to get from the local builder just what he specifies at a low or even a medium price is certain to experience disappointment. But not all custom bodies are poorly built; many of them show exceptional workmanship and materials. The difficulty with

Fig. 1—Standardized Sectional Panel Body Showing the Principal Sectional Units in Approximately Their Proper Relative Positions

such bodies is that the price is disproportionately high, and even the best of them, constructed with the most conscientious care, are usually deficient in some particular. The making of the body is based on the more or less restricted experience of the builder who, as a practical man, following custom, has exaggerated the care and expense above the true requirements in certain details. Under the critical inspection of a competent engineer, wasted effort will be evident in the construction of virtually all good custom-bodies. In his anxiety to turn out a durable product and always "throw any errors on the safe side," the small, scrupulous builder is inclined to use timber a little larger than necessary here and there and place heavy and elaborate iron forgings where they can do no good. All of this adds to the price and, as increased non-pay load, permanently reduces the efficiency of the vehicle by just that much as a transportation unit.

The dealer is quick to realize the loss he sustains through delayed deliveries of the chassis while he waits for a body to be built. Both dealer and customer are aggravated and suffer a substantial loss during this period of waiting, which may run into weeks after the truck is sold. The tying-up of the dealer's money in chassis inventories presents a retardation in the process of merchandising that cannot be ignored by the chassis builder. He should be just as much interested as the dealer in having his chassis promptly placed in active service, for idle equipment represents an investment earning no interest, a definite economic waste that, like time itself, cannot be recovered.

This plan of body handling leaves the dealer almost powerless in rendering service to the buyer in matters of repair, all of which are likely to prove relatively expensive in both time and direct cost; a condition that is rendered more exasperating by enforced total loss in earning capacity of the vehicle while it is laid up for repairs, which commonly takes considerably more time than the proportionate value of the parts affected, because the custom body-builder habitually gives little or no attention to the incorporation in his product of features that will facilitate rapid and economical repair.

Standardized Sectional Bodies

The successful operation of the *fourth* plan has been made possible only comparatively recently owing to a lack of sufficient demand and the continuous evolutionary changes in body requirements as the business developed. Through the adoption of this plan the chassis builder and his dealer derive a great many benefits. Not the least of these for the former is complete relief from the undertaking of body-building. While eliminating the capital investment involved in the *first* plan, he simultaneously removes from his dealers the burden of body inventories common to the *first* and *second* plans. Moreover, he is assured that his chassis will not be abused by being made to carry a poorly proportioned or ill-fitting body of excessive weight or capacity. The dealer is further helped by overcoming the slowing-up of merchandising while waiting for each body to be built individually under the *third* plan.

To assist in getting a clear understanding of the development and possibilities of this whole scheme, a distinction will be made between the different sizes of chassis used for commercial purposes, dividing them into the following classes:

(1) Commercial chassis, requiring a "commercial body," comprising all light popular chassis, whether designed primarily for passenger or commercial purposes, with a rating of less than 1 ton

(2) Truck chassis, rated at 1 to 1½ tons, requiring a truck body

(3) Truck chassis, rated at 2 to 2½ tons, requiring a truck body

(4) Truck chassis, rated at 3 to 5 tons, requiring a truck body

The plan involves the production of a complete standard line including a number of styles of body for each chassis.

The large volume of trade available in a single design of chassis early in the commercial-car business made possible the successful beginning of standardization in stock bodies for the first class of vehicle and, as bodies for both the first and the second classes have now been standardized thoroughly, they can be treated, not as a theory, but as a matter of practical accomplishment, and the results regarded as an indication of what can be accomplished by the standardization of heavy-duty trucks.

The prospect of a large market for these lighter bodies has permitted the treatment of body design, production and maintenance as engineering problems to an extent never before realized in the body field. The needs of every large class of users have been analyzed thoroughly and standard types developed, each with features that fit it to the actual requirements. There is occasionally some exceptional service that cannot be satisfied by any possible standard, but the vast majority can find what they want in the standard types. The demand for infinite variety is founded on custom and prejudice rather than practical experience or analysis, and a trial usually convinces the buyer that the design of the standard body for his use is based on a more comprehensive and accurate study of his requirements than he could possibly make for himself.

By building the bodies in sections and standardizing these sections, it has been found possible to use certain sections for very many different types of these bodies. In some respects, the scheme parallels, although in a very different field and with much greater economic possibilities, the flexibility and utility of the sectional bookcase. Standardization has been carried to such an extent that the reduction in the total number of component parts has diminished noticeably the body-builder's investment in raw materials, work in process and finished goods.

Many major parts of bodies and cabs are interchangeable on various types of body. Starting with one platform or base, a choice can be made from several side-panels, rear sections and tops, thus making it possible to assemble any one of, literally, a dozen body styles on this one design of base. Likewise, doors and windshields used on cabs or vestibules can be assembled interchangeably with a variety of other body units. In fact, windshield, vestibule doors, vestibule side-windows, rear doors, toe-boards, cushion and lazy-back are worked out readily, each in a single-unit design common to all bodies of whatever model where any one of these items is required. A single endgate can be used to equip many different models.

Fig. 1 shows several of the principal sectional units of a panel body, and illustrates how these units can be built easily into a substantial assembly. Fig. 2 shows the interior of the same body partially assembled with the rear door in place. Interior and exterior views of a vestibule door common to all closed-vestibule bodies is shown in Fig. 3, while Fig. 4 clearly indicates a standard seat-cushion and lazy-back construction.

Fig. 5 illustrates the six consecutive operations in

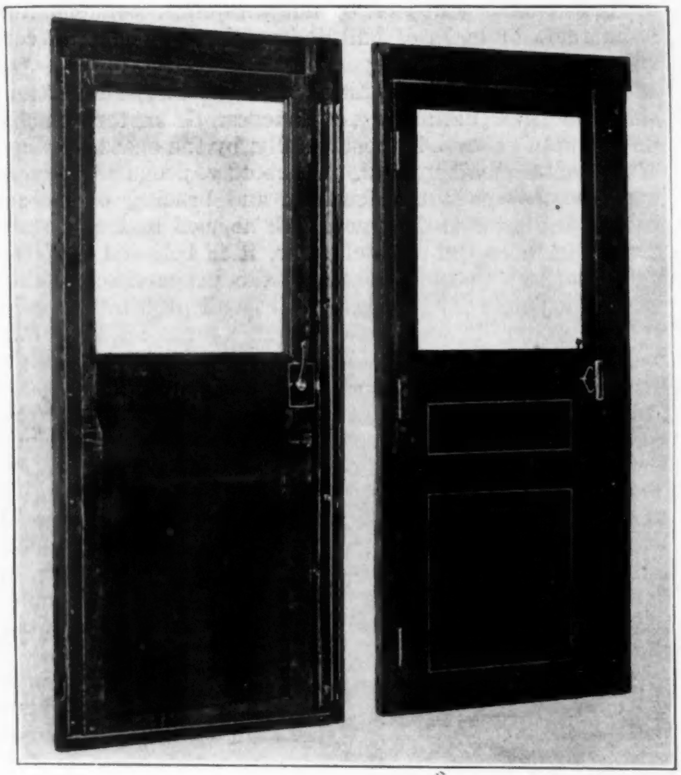


Fig. 3—Interior Side of the Vestibule Door Section at the Left and at the Right the Exterior

the assembly of a six-post express-body with a vestibule compartment for the driver, including doors that can be held open by a special fastener when it is desired to use the body with an open front. An inspection of these illustrations, taken in order, demonstrates how, beginning with the platform, the side-panels, the toe-board brackets, the seat, the top, the endgate, the toe-boards, the windshield and the vestibule doors are added as separate unit-sections to make up the complete body. An examination of these views also serves to make clear how comparatively easy it is to replace any section in overhauling or repair.

Standardization on a few stock sizes of lumber has made possible its purchase under carefully prepared specifications that insure a quality best suited to the purpose at reduced prices. In the case of the heavier frame and platform members it permits the direct shipment of properly conditioned and seasoned fully machined parts from the lumber-mill to the body assembly plants. This reduces the weight to a low minimum before shipment, since it is fully dried instead of green and all waste in the machine-finishing of the parts occurs at the lumber mill before shipment. The total cost of freightage is still further reduced by replacing the double haul from the lumber-mill to the fabricating plant for machining and then on to the assembling plant, by a single shipment from the mill direct to the assembling plant. By adopting efficient quantity-production methods in the manufacture and subassembly of parts, substituting machine for hand labor and manufacturing and fabricating the parts and units under steel jigs, the quality has become more uniform and better at a reduced cost, which has been lowered still further by simplifying operations, decreasing the number of operations and making possible the employment of a less skilled class of workmen.

In no phase of the body-builder's activities is the gain of the standardized sectional body over the earlier forms of construction more evident than in freight shipment. Whereas only six bodies, completely set-up, can be shipped in a 40-ft. freight-car, this number can be increased to a maximum of 16 by having them "knocked down". After the bodies are completely built and set-up by body-makers and have been put through the painting and trimming departments they are sent to the shipping department where the tops and sides are disconnected and then crated for loading in the car. Sectional units for 40 bodies can be packed in the same car, with a much lower rate classification, effecting a striking saving in freight-cost and in the labor of assembling, disassembling and crating.

To pass a maximum of these economies on to the dealer and insure continuous service to the user, the advantages of this plan are still further extended by establishing factory assembling-branches in all large distributing centers, carrying complete stocks of bodies and parts and well equipped for mounting, painting, lettering and repairing. The body sections, as received from the fabricating plants by those branches, occupy a minimum of storage space and need be assembled only to care for sales demands. At first many were skeptical concerning the possibility of turning out body sections with sufficient accuracy to make all parts interchangeable and permit assembly in the fabricating plant, at assembling branches or by dealers themselves. Of course, it had been fully established that this could be done in the case of machines composed of all-metal parts, but it had to be demonstrated that this is not rendered impracticable in a combination of wood and steel by the expansion and contraction of wood caused by variations in moisture and temperature. While it is true that extraordinary care must be taken in the selection and conditioning of the lumber and finished

Fig. 4—Construction of Seat and Cushion Units

wood-parts, all this attention, in quantity operations, results in little additional expense, and this is more than offset by improved quality in the product as compared with bodies built under less exacting conditions.

Metal Bodies

While the all-metal body may, apparently, offer attractive features from the standpoint of quantity production, as affecting the purchase price, it must not be forgotten that maintenance cost and useful life, or depreciation charge, are equally and frequently more important in determining the maximum utility of any transportation unit. The railroad freight-car probably offers as close a parallel to motor-truck bodies in the requirements to be met as can be found in any long-established business. The experience of the railroads with all-metal freight-cars certainly does not justify the conclusion that metal truck-bodies will find very general acceptance in the near future, although the all-metal body will, undoubtedly, continue to meet the demands of certain restricted classes of motor-truck haulage. Some of the railroads recently have converted all their steel coal-cars into the so-called "composite", wood and metal, cars, substituting wood for the steel floor-plates, side-sheets and hopper-doors. Others unconditionally recommend the wood body on account of the corrosion of the steel.

The history in the railroad industry is, briefly, that for many years freight-cars were built altogether of wood, with only sufficient steel parts to tie it together. About 1890 a few firms started to build steel cars. The industry was stampeded and there was a rapid revolutionary movement to the steel car, and, as usual, the pendulum swung too far, forcing great loss upon all concerned before the industry could recognize the advantages of both lumber and steel properly combined and each used in its proper place. The result at the present time is the composite car, which the master car builders have found to possess advantages in all essential factors.

The first cost of the composite car is much less, quality considered, than that of the all-steel freight-car. The average cost of repairing composite cars is less than 40 per cent of that of steel cars in the same service, and the former can be repaired in one-half the time necessary to repair the latter. Furthermore, the composite car can be repaired fully with many materials locally available and without any special equipment, while the all-steel car can be repaired or rebuilt only in a manufacturing establishment equipped with special presses and machinery representing no inconsiderable investment. One of the factors seriously entering into the maintenance and depreciation charges is the fact that in case of a bad accident an all-steel car is frequently almost a complete loss, due to the practical impossibility of economical repair. Railroad operating officials have come to regard the steel car as an unwarranted transportation cost in view of the period of their actual worthwhile service being limited to 10 years; whereas the life of ordinary composite equipment under normal conditions is at least 20 years. Thus both the reproduction value and the actual depreciation of composite cars are less than these costs for all-steel cars.

The average composite car weighs approximately 1000 lb. less than corresponding steel cars. The wood sides do not bulge as the sides of steel cars bulge. The composite car is better for shippers in packing and loading, since greater protection is obtained for the contents of the car, and no precautions are necessary against rusted side-sheets, bulging ends, condensation from roofs or leaks of bulk lading through holes in corrugated sheets.

The all-metal underframe for freight cars, unquestionably, has been justified by experience. In motor vehicles its function is served, substantially, by the chassis frame. While metal members will, undoubtedly, prove of increasing importance in the framing and bracing of motor-vehicle bodies, and designers will do well to incorporate gradually more light metal parts, it is believed that the deficiency of metal in some of the properties, notably resilience, required in truck bodies will prohibit its general adoption to the exclusion of composite wood and metal body-frames. The excuse for metal end-panels does not exist in motor truck as in freight-car bodies.

The advantages of first cost demonstrated by the composite freight-car apply in the same manner, although possibly to a less degree, to motor-truck bodies. The item of maintenance and repair should result in an even greater advantage for the combined wood and metal body as compared with the all-metal body upon which only minor repairs can be made outside a specially equipped shop. Even when such a shop is available, major repairs cannot be made, without unwarranted difficulty and expense, if at all.

A vehicle operating on the streets and public roads is caught in a collision or otherwise damaged so much more frequently than a freight-car operating upon steel rails of a private right-of-way, that the occasion for repairs becomes greater, and, when necessary, a metal-braced and reinforced wood body can be repaired quickly and cheaply with material generally at hand, by an average workman. A steel body, on the other hand, whose parts are specially formed and held together by welding, riveting or some other permanent jointing, presents an expensive, if at all practical, repair job. The same properties that make for difficulty in repair work also restrict or entirely eliminate one element of service that is decidedly in favor of the composite body; namely, there are many little utility changes that the user may need to make to meet the requirements of his own business better. In the composite body, with lumber as the principal material, a saw will readily remove any portion and any handy carpenter with nails and screws can make any desired change easily.

The decrease in weight effected through the use of the composite body, as compared with the all-steel construction, is of even greater importance in the case of the motor car than of the railroad car. To a certain extent there is less likelihood of damage resulting to the load from the body itself where it is made of wood instead of steel.

Advantages to Dealer

The accumulated savings due to increased purchasing power, elimination of waste, economical production and distribution methods, and reduced labor, freight and storage charges, when passed on to the dealer, enable him to offer his customers the combined unit of chassis and body at a lower price than it can be secured by any other practical solution of the body problem. These combined benefits can be attained only by quantity output, assured through national distribution of a very complete line and accompanied by the ability to equip not only the chassis of one but those of several of the largest builders.

The lower price at which standardized production bodies can be sold benefits the dealer directly through increased sales. The dealer's volume of sales is further

extended by the development of large new fields for the sale of chassis, made possible by the creation of standardized body-types especially suited to these fields. In fact, the body builder has been, and still is, doing as much as, if not more than, the chassis builder in developing new fields for the use of commercial cars. The opening of new provinces of employment for the motor car by the creation of special bodies is well illustrated by the variously called park, country-club or suburban bodies. Thousands of light chassis with these bodies are now sold every year, and their sale is increasing very rapidly. Well-to-do people, with country estates or suburban homes, frequently use a light, popular-priced chassis with this body as a general utility car for taking passengers, baggage or freight to and from the railroad station, marketing, going to the golf club, or general knockabout purposes.

Not the least of the advantages to the dealer is that

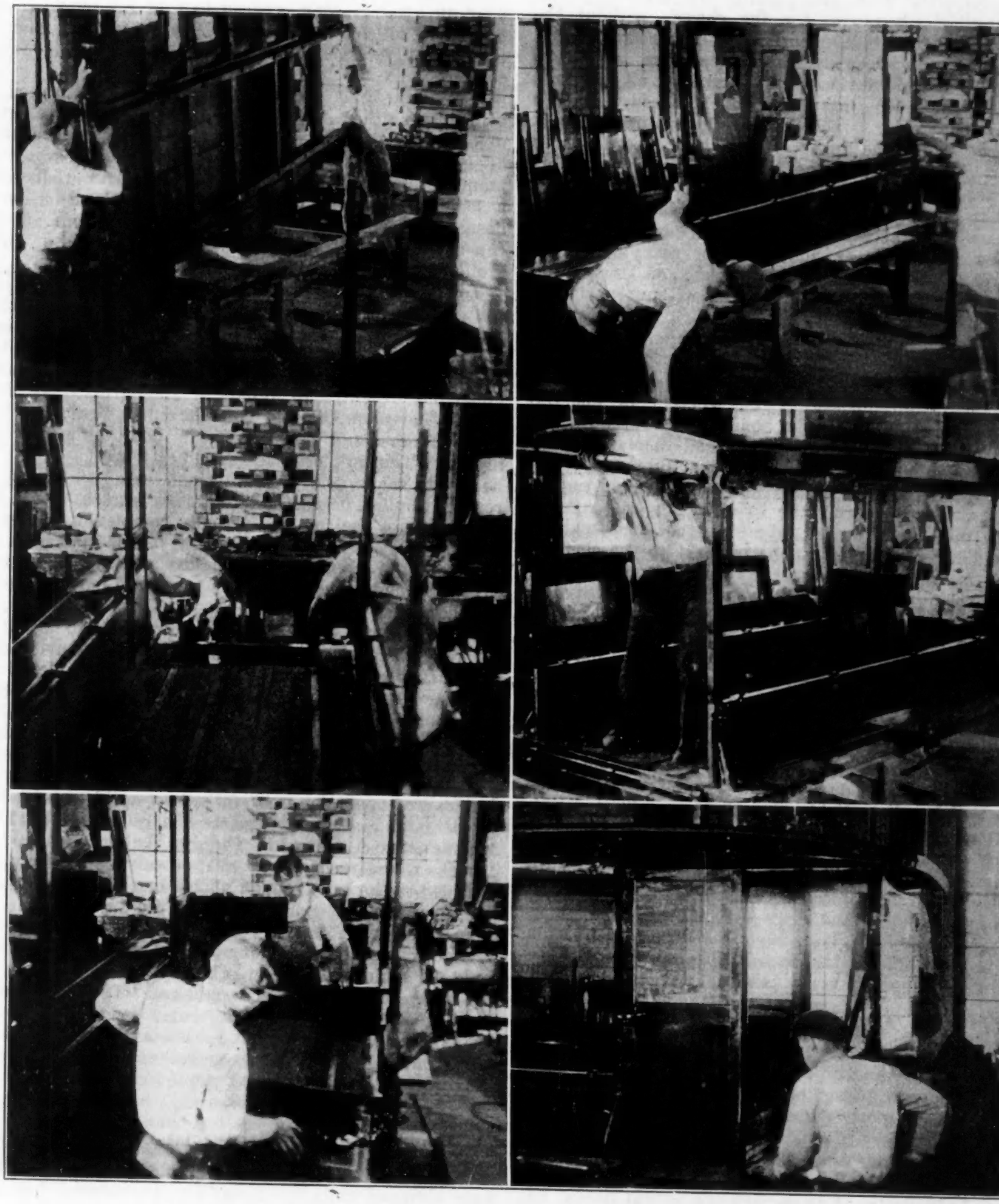


FIG. 5—SUCCESSIVE STAGES IN THE ASSEMBLING OF THE STANDARDIZED SECTIONAL BODY
The Upper Pair of Views Show the Body Platform Being Placed in Position for Assembly and the Side Section Being Mounted Respectively. In the Middle View at the Left the Toe-Board Brackets Are Being Attached and at the Right the Top Is Being Put On. The Tail Gate Is Being Placed in Position in the Lower Left Corner and Adding the Vestibule Doors and the Toe-Boards, Which Are the Last Steps, Are Shown in the Lower Right

of immediate delivery. In common with most purchasers, the commercial-car or truck prospect generally postpones the buying of a new vehicle as long as possible but, when finally he is persuaded to close a deal, he wants the car immediately. It may be that his old chassis has broken down suddenly, or that additional transportation must be provided for at once. In any case the buyer does not want to wait. Consequently, the dealer who can make immediate delivery of the chassis complete with body, ready for service, has a very tangible advantage, for the chassis without the body is of no use to the purchaser. To reap the full benefit of prompt delivery, the dealer must be able to offer a sufficiently wide line of types to meet all the usual demands. With the assistance of the body-builder's engineers the dealer is able to give the customer expert advice regarding the type of body best suited to his business. Furthermore, the body builder, through his branch assembly-plants, is prepared to give the buyer not only what he needs but what he may reasonably want in the way of special painting, lettering, accessories, numerous variations or additions, in rear and front enclosures, shelves, partitions, doors, etc., so long as the standard basic sections are employed without variation in the design and dimensions.

If the volume of his business is sufficient, the dealer can carry profitably on the floor of his own showroom various bodies, the "best-sellers", mounted on his chassis for demonstration purposes. But whether or not the chassis dealer exhibits sample bodies, the body builder's branch should maintain salesrooms and displays where the dealer can show his customer exactly the type of body he is to get. Incidentally, the branch organization becomes a very potent factor in assisting and making sales for the chassis dealer, who finds that often particularly difficult customers can be brought to the closing-point by taking them to the body builder's branch and showing them well-made and well-finished bodies and giving them the advantage of the body engineers' advice as to style and type. Thus, these branches not only carry the necessary complete line of bodies and parts to meet the needs of dealers and customers, but they render many helpful services to both in turning out the fully equipped unit.

Not only does the dealer benefit by increased chassis sales, but by handling the body sale he realizes an additional profit on the body itself in discounts in which he is protected by the reliable manufacturer. This profit, while attractive to the dealer, does not detract seriously from the economies effected by quantity production.

With this scheme of body supply the dealer not only avoids tieing up his capital in carrying a stock of bodies but, by quicker sales and more especially by immediate delivery and collection, he is able to reduce the time his money is lying idle in the chassis by from three to six weeks, or even more in many cases.

Advantages to User

That which helps the dealer benefits the chassis builder indirectly, and, to a great extent, the advantages that they enjoy are passed on to the owner and operator. Better bodies at more attractive prices and immediate delivery are the first of these benefits to appeal to the user. When he finds that without losing any of these he can obtain, generally, exactly what he wants and, if not, a body designed to satisfy his actual needs, he is not likely to look further in making his initial purchase of body equipment. It is after purchase, however, that he experiences the greatest advantage of this method; namely, prompt, effective and economical service and repair. If he has been a user of custom-built bodies, individually fitted together by hand by body-builders, he has learned that they are usually framed so that in case of damage it is almost as expensive to repair a body as to purchase a new one. Also, he has found that the small body-builder, after supplying the original body, makes no pretense of giving service on the body. Under these conditions the user not only has to pay the local small shop an excessive price for repairs but he must bear an even greater expense in that his whole investment in the chassis and the body is tied up and his business suffers heavily while his equipment is out of commission.

A standardized sectional body can be smashed by collision or other accident and, regardless of the extent of damage, within a very few hours any damaged piece, or entire sections, can be replaced, if necessary. The manufacture of interchangeable body-parts, reduced to a low minimum in variety, coupled with attention in design to facilitating replacement, offers about all that can be expected reasonably in the possibilities of quick, economical repair.

The extent to which these possibilities have been realized in actual practice is well illustrated by three typical cases. One of the large accident-insurance companies, in the settlement of a claim for damages to a 1-ton truck partially wrecked by a street-car in St. Louis, undertook recently to repair a standardized sectional body. Three quotations were obtained, two from local body-builders and one from the body builder's local branch. The builders each required 2 weeks to put the body into shape, and the quotations were $168 and $192, respectively, while the body builder's branch quoted $52, naturally got the job and actually completed the repair, putting in a new side and a new panel, in 2 hr. time. A Boston truck-gardener skidded across the Charles Street Bridge, smashing a side-panel and part of the top of the truck body. Having but the one truck, he needed it every day and could not afford to lay it up for repair. Fortunately for him, it was a standardized sectional body, and the builder's branch replaced the side panel and top and had the truck back on the street in 18 min. A dairy company operating a fleet in New York City, building its own bodies and maintaining repair and paint shops, purchased three sectional bodies because they had to have equipment at once. On the first day of operation one job had an accident, smashing a side-panel and the top against a pillar on the Third Avenue elevated railroad. Finding that it would require 2 weeks to make the repair in its own shop, the company appealed to the body builder's local branch, which turned the job out in the regular course of the day's work in less than 5 hr.

Similar examples of prompt and economical service could be added indefinitely, but these are typical and indicate what has been accomplished. The fact that all parts and body sections are built on thoroughly co-ordinated jigs, thus insuring easy assembling and the perfect fitting of all parts, makes possible such exceptional low cost and speed in handling repairs and replacement.

Standardization of Commercial Cars and Trucks

The largest builders of light chassis have modified their stripped chassis offered for commercial purposes to accommodate the mounting of existing models of

(*Concluded on page* 211)

Internal-Combustion Engine Fuels

By C. A. Norman[1]

Minneapolis Section Paper

AFTER pointing out that although kerosene costs less than gasoline at the present time and is a cheaper fuel for the farmer to use, the author states that if the industry continues to construct tractors designed to use kerosene as fuel it will not be long before the cost of it is the same as that of gasoline. He argues that automotive engines should be designed to run on any liquid fuel and gives figures on the available supply of petroleum products and distillates in the world at the present time. The requirements laid down by the Government for gasoline are mentioned and it is stated that it is not possible for the oil industry to supply generally to the trade a gasoline meeting the recently adopted Government specifications which the author considers are very lenient. The possibilities of utilizing the cracking process to increase the gasoline supply are referred to but the author considers it economically sounder to develop automotive engines to run efficiently on uncracked fuel, pointing out what has been done abroad in developing the injection type of engine for airplanes, automobiles and tractors.

A table giving data on practically all of the liquid fuels that have been considered in the past five or six years is presented and the advantages and disadvantages of these are brought out, together with information on the available supply. Considerable attention is paid to the possibility of utilizing the various farm-product sources of alcohol and the conclusion is reached that such utilization is not practicable under the present prices that are being paid for various products. Mention is made of a process that is being employed in Switzerland for producing alcohol from coal. In conclusion the possibilities of utilizing oil shales as a source of fuel are emphasized.

I UNDERSTAND that you are interested in fuel substitutes, that you have tried to construct tractors to utilize kerosene as fuel and that you have had trouble with kerosene. If I ask why you have been designing tractors to run on kerosene, your probable answer will be that kerosene costs much less than gasoline and is a cheaper fuel for the farmer to use. This condition may not endure, however. It is as difficult to produce kerosene as it is to produce gasoline. If you continue to construct tractors to run on kerosene, in a short time kerosene will cost as much as gasoline.

The prices in Kansas City are a fair example of the price movement of kerosene within the past few years. In 1917 the market price there was 6.8 cents per gal., but that price had increased to 17.6 cents by June 30, 1920. In 1917 gasoline was 18.2 cents per gal. and by June 30, 1920, it had increased to 26.2 cents. The increase in the price of gasoline was 44 per cent and that of kerosene 160 per cent. Kerosene in 1917 cost only 37 per cent of what gasoline cost at Kansas City; in 1920 it cost 67 per cent of what gasoline cost. The production of kerosene has increased very little. In 1909 we produced 40,000,000 bbl. and in 1919 55,000,000 bbl., an increase of something like 37 per cent; at the same time gasoline production increased from 15,000,000 to 94,000,000 bbl., an increase of 600 per cent.

Our home use of kerosene reached its minimum in 1916; it was very small. From that time the home use has increased and the exports have decreased. There is a parallel between the great increase in price and the increase in home use. Tractors came into use after 1916 in tremendously increasing numbers and the growing use of kerosene in tractor operation had much to do with the rise in the price of kerosene. I am therefore justified in saying that the more tractors are adapted to run on kerosene, the higher the cost of kerosene will become. Before the development of anything new is begun, it is of extreme importance to consider carefully the fuel situation and the economic conditions that must be met; otherwise we might find that after years of effort we had produced something of no economic value whatever.

Regarding the present necessity, my opinion is that engines should be designed so that they will run on any liquid fuel; not only to run on gasoline or kerosene, but on a mixture of the two. I think that can be done. I will try to show what we have available in the world today in the way of petroleum products and distillates of petroleum, so that we may know the rational line to follow in tractor design to meet the fuel situation as it is.

Available Supply of Petroleum

We have to-day, according to David White, about 7,000,000,000 bbl. of crude oil in the United States that can be extracted from the ground by present-day methods of production. Those methods are very inefficient. J. O. Lewis, of the Bureau of Mines, states that probably about 50 to 70 per cent of the crude oil is never extracted but remains in the ground. The experts in the Bureau of Mines have accomplished much toward improving the methods of extracting oil. The consumption of crude oil in the United States at present is over 400,000,000 bbl. per year. This means that our petroleum resources may be exhausted in something like 14 or 15 years. The question is, what will happen then?

We know that long before such a condition occurs production will commence to drop. Mr. White's estimate seems to be that the maximum production of crude oil for the United States will occur about the year 1925. Up to that time we will produce 450,000,000 bbl. of crude oil per year; after that the United States' production will go down. We actually consume in this country about 450,000,000 bbl. per year at present; so, from 1925 on, it will be a physical impossibility for this country to produce the crude oil it needs. Where is the remainder to come from. During the war we were looking for substitutes such as alcohol and benzol. We found we had tremendous shale-oil resources. We found also that there are very large petroleum resources outside of the United States. At the Petroleum Congress in November, 1920, in Washington, the predominant note was that we ought to be able to get into all oil fields beyond the boundaries of the United States, no matter where they are, on an equal footing with everyone else and derive our oil mainly from abroad.

In 1919 we imported 53,000,000 bbl. of oil from Mexico. We exported 60,000,000 bbl. of petroleum products. We could have eliminated the importation if we had kept all our petroleum products at home. However, at present we are importing from Mexico 60,000,000 to 70,000,000 bbl. and are actually depending upon the outside

[1] M.S.A.E.—Professor of machine design, Ohio State University, Columbus, Ohio.

world for our crude oil supply to the extent of perhaps 20,000,000 bbl. The question is, can we continue to do that? The best estimates that can be procured are made by Eugene Stebinger, of the United States Geological Survey, who is an expert on foreign oil fields. There is a small supply in Canada; in Mexico about 4,500,000,000 bbl.; in Northern South America, including Peru, 5,700,000,000 bbl.; and in Southern South America about 3,500,000,000 bbl. That includes about all the supplies of oil in this hemisphere. We find oil in quantities of, roughly, 5,500,000,000 bbl. available in Persia and Mesopotamia, 5,500,000,000 bbl. in Russia and 3,000,000,000 bbl. in the East Indies.

Can we get this oil if we want it? Here we are faced with a most startling situation. It appears that while we have been exhausting our natural resources at a terrific rate, Great Britain has put oil resources under her commercial and in some cases her political sway, all over the globe. She controls at present, directly and indirectly, 75 per cent of the world's future oil supply. The oil in Persia is controlled by an agreement with the Persian Government. The oil in Mesopotamia is controlled jointly by France and England. Holland shuts out all nationals except the Dutch from the exploitation of oil in Java. In other places British capital simply is in control. We must compete with Great Britain to obtain oil from the countries on this side of the globe.

If we do not want to be dependent upon foreign countries for our fuel supply, we must face the situation that within three or four years we cannot supply our present need of crude petroleum, and look for available substitutes that we can get within the boundaries of the United States. In seeking a substitute for petroleum we might perhaps not wish to substitute something akin to crude oil. We do not use the oil as crude oil; in most cases we use it in other forms. In 1919 this country consumed 88,000,000 bbl. of gasoline. The total amount of gasoline extracted from crude petroleum was slightly over 23 per cent; that is more gasoline, so-called, than is actually obtained in petroleum naturally. The specifications issued originally showed that gasoline was the portion that distilled over below 150 deg. cent.; that is, below 300 deg. fahr. We know nothing of such gasoline to-day. The Government now specifies three grades of gasoline; first, the finer grade of aviation gasoline that has an end-point of 329 deg. fahr.; second, the domestic grade of aviation gasoline that must distill over below 374 deg. fahr., and third, ordinary engine gasoline used for passenger cars and trucks, which must distill over below 437 deg. fahr., an increase over former Government specifications which called for 425 deg. fahr. The question arises whether those specifications are actually met at present. The Bureau of Mines conducted an investigation in seven of the largest States. It was found that there was a great quantity of gasoline in each of these States that did not meet the very lenient requirements, and further that the average gasoline for the country did not meet them and that the average gasoline in the United States had an end-point of 456 deg. fahr. At present it is not possible for the oil industry to supply generally to the trade a gasoline meeting the most lenient specifications that the Government considers it advisable to adopt. This means that we are faced with an emergency.

Boiling Points and Specific Gravity

I wish to comment upon our unfortunate habit of buying gasoline by its specific-gravity rating. What we want is a fuel that we can send through the carbureter and the inlet-manifold to be picked up readily by the air and go as a uniform mixture into the cylinders. This requires a certain volatility; that the fuel evaporate easily; that the boiling point have a certain maximum value and that the heat of evaporation be not beyond a certain maximum value. But it makes no difference what specific gravity the fuel has. Alcohol and benzol weigh considerably more per gal. than gasoline. Benzol distills over entirely at 176 deg. fahr. and alcohol at 172 deg. fahr. They are both very much more volatile than gasoline so far as the boiling point is concerned, and yet they are heavier. So, we must remember the boiling points and disregard the specific gravity. Selling gasoline by its specific-gravity rating may be of advantage to the oil companies. They may produce an oil having very heavy fractions that they mix with light fractions. This, however, may result in a fuel, part of which will not evaporate in the manifold at all, while part will be so volatile as to be inconvenient and dangerous. The Baumé scale will show it to be all right as regards specific gravity, but as a fuel it is all wrong. One-half of it is too light and the other half is too heavy to evaporate. We should eliminate the buying of fuel by its specific-gravity rating; we should buy it by its distillation test.

Cracking

It is a serious matter that the average gasoline of the United States does not meet what the Government considers a satisfactory specification for gasoline. The oil companies have been forced to adopt this deteriorated grade of gasoline on account of the automotive demand. We have come to the point where there is one automobile for ever 12 inhabitants of this Country. One can calculate readily the enormous demand thus constituted. It is a demand that cannot be supplied without straining our idea of what gasoline is and adopting new production methods. One method now being used is to compress and refrigerate natural gas. In that way we obtain so-called casing-head gasoline; present-day gasoline contains about 7 per cent of it. We can crack low-grade oil and produce gasoline. The Standard Oil Co. has done that for a long time, using the Burton process of cracking under pressure. The Bureau of Mines has worked out another method, the Rittman process, which also produces gasoline from raw fuel. The Burton process is a commercial success and present-day gasoline contains about 8 to 10 per cent of cracked gasoline. The Rittman process seems to be a success, judging from the published reports, but its use has not spread very fast. By those two processes it is possible to produce from heavy and from light distillates a large quantity of gasoline. Rittman claims that he can convert 80 per cent of the original oil into gasoline. This would mean that we would have twice as much gasoline as we use and need in this country at present, or for some time to come. Arthur D. Little, Inc., a chemical engineering firm in Boston, has issued a pamphlet which seems to indicate, as its opinion, a cracking limit of 60 or 70 per cent. From our present production of crude oil we could then produce by cracking something like 300,000,000 bbl. of gasoline, and that would supply our automotive needs for some time.

Injection-Type Automotive Engine

However, cracking involves labor and considerable material. If we can develop automotive engines to run efficiently on uncracked fuel, this would certainly be a sounder solution of the fuel problem than cracking. It is well known that we have stationary and marine engines

that utilize uncracked fuel. In Germany, the Junkers airplane engine also seems able to do this. It is an injection-type engine, operating on a somewhat modified Diesel principle. In France the Bellern and Bregeras engines, operating on a more modified injection principle, have been successful in automobile operation on kerosene. In England the Blackstone injection engine has been adapted to a tractor; and news has come of the Steinbecker injection engine being adapted to automobiles in Germany. So the injection-type automobile engine is already more than a dream. Very possibly we have not in this country at the present time an injection engine that could be turned over to an untrained farmhand to operate. But if one-tenth of the effort now spent on the carbureting engine were concentrated on the automotive injection engine, it is certainly not unreasonable to expect that we would have a practical automotive injection engine in a short time.

The great trouble is that the carbureter engine in automotive service is extremely inefficient. When running cars on the road we do not use more than 20 per cent of the maximum power of the engine. With such loads 150 per cent more fuel per horsepower-hour is required than at full load, while the Diesel or injection engine will run more economically at one-half than at full load, and at one-quarter load may require only 15 per cent more fuel per horsepower-hour than at full load. I think the present situation indicates that the latter type is the most desirable engine. With its aid we could save 50 per cent of our fuel. Instead of having our fuel resources exhausted in 15 years, they would not become exhausted in less than 30 years. This sort of thing is being done in Germany and it can be done here. We ought to worry about this more than about fuel substitutes. Commenting on the attempts that have been made to improve the performance of the carbureter engine, a trade paper[2] states that by introducing an extra inlet-valve on the engine, which is never throttled, the mileage on automobiles has been doubled. The paper by A. L. Nelson on the Fuel Problem in Relation to Engineering Viewpoint[3] contains other suggestions about how to obtain fuel economy. These papers should be read with great care and the suggestions contained therein followed.

[2] See *Automotive Industries*, Jan. 27, 1921, p. 185.
[3] See THE JOURNAL, February, 1921, p. 101.

SUBSTITUTE FUELS

Table 1 shows about all of the liquid fuels that have been considered during the last five or six years. It includes the fuels that were developed in Germany under war stress. The Germans had no crude oil, but they had available and used some of the fuels in Table 1.

TABLE 1—HEAT VALUES AND AIR REQUIREMENTS OF VARIOUS AUTOMOTIVE FUELS[4]

Fuel	Illustrative Analysis, per cent					Average Lower Heat Value, B.t.u. per lb.	Theoretical Air Requirement per Lb. of Fuel, lb.	Boiling Point, deg. fahr.	Heat of Evaporation, B.t.u. per lb.
	Carbon	Hydrogen	Nitrogen	Oxygen	Sulphur				
Coke Oven Tar[5]	89.45	6.59	....	3.96[9]	....	14,700-15,700	12.3	...	...
Commercial Benzol	91.50	7.80	....	.....	....	17,300	13.3	176	167
Creosote Oil	80.11	9.70	8.90[10]	.....	1.30	15,600	12.5	...	...
Crude Oil	84.00	12.00	....	1.00-4.00[9]	....	17,000-21,000	13.9	...	...
Ethyl Alcohol[6] 95%	52.12	13.14	....	34.74	....	10,800	8.6	172	372
Ethyl Alcohol[7] 90%	52.12	13 14	....	34.74	....	10,200	8.2	172	372
Fuel Oil	86.30	12.50	....	1.20[9]	....	18,000+	14.0	...	...
Gas Oil	86.30	12 65	....	.....	....	18,000	14.4	300-750	300[11]
Gas Tar	89.45	6.59	....	3.96[9]	....	14,700-15,700	12.3	...	...
Gasoline	85.10	14.90	....	.....	....	18,000	15.0	140-437[12]	150
Kerosene	85.20	14.12	0.60[10]	.....	....	19,000	14.8	292-600[12]	250[11]
Methyl Alcohol	37.50	12.50	....	50.00	....	8,400	6.5	150	480
Naphthalene	93.75	6.25	....	.....	....	17,300	13.0	422	..
Sulphuric Ether	65.00	13.50	....	21.50	....	15,900	11.3	96	162
Toluol	91.50	8.50	....	.....	....	18,300	13.5	232	150
Water Gas Tar	91.00	7.40	1.60[10]	.....	....	16,200	13.0	...	...
Xylol[8]	90.60	9.40	....	.....	....	18,500	13.8	288	146

[4] From a bulletin of the Ohio State University.
[5] From dry distillation especially in vertical retorts.
[6] 95 per cent by weight. The composition given is that of pure 100 per cent alcohol.
[7] 90 per cent by weight. The composition given is that of pure 100 per cent alcohol.
[8] Approximate average.
[9] Total of nitrogen, oxygen and sulphur.
[10] Total of nitrogen and oxygen.
[11] Including heating of the liquid above average atmospheric temperature.
[12] Present end-point in Government specifications.

Gas oil is available in this country in small quantities and we throw it away. The gas works use it to enrich illuminating water-gas, but there is no need of this. In former days, when we used open-flame gas-jets, we needed a luminous flame; now we use gas-mantles and want a non-luminous flame. We do not need rich gas for lighting purposes now; city ordinances that require the gas companies to enrich illuminating gas with gas oil are antiquated and unintelligent.

Benzol has been tried out as a fuel by the Germans. It is obtained as a by-product from the manufacture of gas in this country and we get about 4,400,000 gal. per year in this way. As a by-product from coke ovens we secure about 44,000,000 gal., so that the total supply of benzol in this country is about 50,000,000 gal. per year. That could be increased very largely if we coked all of the 500,000,000 tons of coal we use in this country per year. We would obtain 2 gal. of benzol per ton of coal, or 1,000,000,000 gal. or, roughly, 20,000,000 bbl. of benzol, which is much less than we need. We need 100,000,000 bbl. of automotive fuel at the present rate of using it; so, the benzol would supply one-fifth of what we need. Benzol contains less hydrogen than petroleum, develops fewer heat units per pound, requires somewhat less air per pound, is very volatile and boils at 176 deg. fahr. It is a very good fuel so far as those qualities go, but when it is used in internal-combustion engines there are certain things to guard against.

Benzol is apt to contain a substance akin to resin called cyclopentadiene, which has a tendency to close up the fuel passages in time. That is not a very serious trouble but benzol must be purified with acid to eliminate the cyclopentadiene. Another trouble is that benzol dissolves shellac and is likely to dissolve the coating on the carbureter float. For that reason the float should be made of metal. If a low compression pressure is used, benzol tends to form a fluffy carbon deposit in the cylinders. That is not serious if a higher compression is used than is customary with gasoline; it is eliminated entirely if benzol and alcohol or gasoline and benzol are mixed. There are varying statements regarding carbon deposits when using benzol as fuel. The National Automobile Chamber of Commerce made an investigation during the war by running a six-cylinder Continental engine on benzol. There was no trouble from carbon formation; the engine ran very economically and generated more power than it did on gasoline. Thomas Midgley, Jr. and others say they have trouble with this fluffy carbon in low-compression engines; so, one must be prepared for such trouble if these engines are used. Benzol is being used in this country and in Germany to a considerable extent at present.

The farmer has been told that he could use his corn and potatoes, corn-stalks and the like, by turning them into alcohol. In the city, garbage can be converted into alcohol successfully. Anything that has starch of sugar in it can be turned into alcohol. One bushel of potatoes will make about ¾ gal. of 95-per cent alcohol and we could get 2 bbl. of alcohol from an acre of potatoes if about 110 bu. per acre were raised. In Maine they grow 400 bu. of potatoes per acre. At the rate of 2 bbl. of alcohol per acre of potatoes, 50,000,000 acres would have to be used to produce alcohol enough to supply the automotive needs of the country; which is not a very large acreage. The total farm acreage in the United States is over 800,000,000 acres, and the cultivated acreage is between 400,000,000 and 500,000,000 acres. So, it would amount to taking about 5 per cent of the farm land, or 10 per cent of the cultivated farm acreage, and utilizing it for producing alcohol for internal-combustion engine fuel.

One bushel of corn will yield 2.7 gal. of 95-per cent alcohol. If 28 bu. of corn per acre are grown, we can again get 2 bbl. of alcohol per acre. That may be a larger figure than the average yield of corn per acre for the entire country, but it can be obtained. There again we would need 5 per cent of the farm land or 10 per cent of the cultivated farm acreage to plant to corn to be turned into alcohol. From the standpoint of acreage that would be satisfactory but from the standpoint of price it is not. If we desire to buy alcohol at 40 cents per gal., potatoes must be sold for 15 cents and corn for 50 cents per bu. That would not please the farmer. It has been suggested that waste potatoes and culls be used for this purpose, and that probably is the only method we could countenance in the United States. The situation is different in Europe. During the war gasoline cost nearly $2 per gal. in most of the European countries; it cost over 4 shillings in England. Under such conditions of price it is profitable to turn potatoes and corn into alcohol.

Could we not turn waste products such as straw into alcohol? It is possible to convert 10 per cent of the wheat straw into alcohol. If we figure 1 ton of straw to every acre of wheat land in the country, that gives about 40,000,000 tons of straw available for making alcohol. It has been estimated that 20,000,000 bbl. of alcohol could be produced from the straw. Some people have thought this is the solution of the problem. Henry Ford is building a plant at Detroit to produce alcohol from straw. The trouble is that the straw cannot be left until the kernel of the grain ripens. Straw loses one-half of its alcohol-yielding properties when it becomes dry. Another obstacle is the high cost of collecting the straw from large areas to produce alcohol in vast quantities. While it may not be profitable to turn straw into alcohol, it may be possible to turn the straw into gasoline, although hardly for other than stationary-engine use.

Sulphite liquor is obtained in paper mills as a by-product from cellulose that is manufactured into paper. The alcohol we could get from that source amounts to less than 1,000,000 bbl. Sawdust has also been turned into alcohol in Europe. The sawdust is treated with sulphuric acid. The total amount of sawdust available from all the sawmills in the United States would yield less than 1,000,000 gal. of alcohol.

A most interesting way to produce alcohol from coal has been developed in Europe. Calcium carbide, which is a combination of limestone and carbon, is produced first and by the action of water acetylene is obtained. The next process produces aldehyde and alcohol is produced finally. That is the way they do it in Switzerland. At the prewar rate of exchange the cost is less than 30 cents per gal. Yet the prewar power cost was high, about ½ cent per hp-hr., but coal was higher, about $8 per ton in this calculation. It appears to be a good proposition in that it requires only coal, limestone, water vapor and some sulphuric acid to produce alcohol. This has been done commercially abroad. The Swiss Government has control of the companies that produce in this way. We could do that here but we would need about 16,000,000 hp. to produce all the alcohol we need to run our automotive apparatus. The total water-power of the country has usually been estimated at 25,000,000 hp. on an all-year basis. On a six-months' basis we have 50,000,000 hp.; so, it is feasible to do this.

Alcohol itself attacks iron and copper worse than benzol does; it contains a certain amount of water and that corrodes the fuel ducts. If a rich mixture contain-

ing alcohol is used, combustion will develop acetic acid and aldehyde and that may corrode the cylinders. When using alcohol, the fuel tanks and fuel ducts should be lead-lined and precautions taken against running on an over-rich mixture. The London General Omnibus Co. found the mixture of alcohol and benzol satisfactory in London. We would not find it satisfactory here because it gives a less number of miles per gallon in winter than gasoline. Roughly, only 6 miles per gal. can be obtained with alcohol and benzol mixed half-and-half, as compared with more than 7 miles per gal. on gasoline. Alcohol has the advantage of being a very fine carbon-remover.

Naphthalene is a solid but melts at 68 deg. fahr. Mixing it with benzol, for instance, gives a liquid fuel that operates very well. It is being used in Paris. Only small quantities of naphthalene are available. Ether is of some interest as an engine fuel. It has the same chemical constituents as alcohol. The only difference is that it has a boiling point of 96 deg. fahr.; alcohol has a higher boiling point. Ether mixed with alcohol makes a mixture that starts an engine easily in cold weather. It is sold in England under the trade name of Natalite. Some official results of tests by the Royal Automobile Club of Great Britain show that it is a very good fuel. Ether is produced from alcohol by the action of sulphuric acid and so costs more than alcohol. In South Africa Natalite sells for 3 shillings per gal. as against 4 shillings for gasoline.

As an engine fuel benzol has a very unpleasant property; it solidifies at 40 deg. fahr. Toluol and xylol are substances nearly akin to benzol and are obtained in the same process. If they are mixed with benzol, the freezing point is lowered somewhat. It is lowered still more by mixing gasoline with alcohol. A fuel mixture that solidifies at about 4 deg. fahr. is secured. This is what Germany used during the war. The best test information we have is to the effect that in Germany a mixture of one part of alcohol, one part of benzol and one part of kerosene gave better results in economy and power than any other fuel in existence. It was better than gasoline and better than benzol and alcohol. It is the fuel especially recommended by Professor von Loew, who has conducted most of the tests in Germany.

With a fuel that contains alcohol and benzol the engine compression can be increased. If this is done with the present-day gasoline or kerosene, a knock is produced. Alcohol and benzol will not produce a knock. They burn slowly. For that reason the compression can be increased to 200 lb. per sq. in. When that is done, better power can be obtained from the alcohol mixture than from gasoline. If we increase the compression in engines, provide a lead lining for the fuel ducts and see to it that a lean mixture is used, there is no reason why we cannot run an engine on a mixture of benzol and alcohol; or benzol, alcohol and gasoline; or alcohol and ether; and, perhaps other mixtures, obtaining as good results as we do now from gasoline. However, as I have tried to point out, the obstacles that prevent the utilization of these possibilities are their excessive cost and the enormous quantities we need. The best we could do is to produce alcohol by utilizing our water-power, and benzol from all the coal we use. Even so, however, it would be hard to produce enough of the two to meet our automotive needs. Important quantities could be produced if the emergency arose, but I do not think this will ever be necessary.

Shale Oil

There is a resource from which we can get all the fuel we need in this country and at no unreasonable price. It is oil shale. I do not give my own unsupported opinion. Victor C. Alderson, president of the Colorado School of Mines, has made oil shales his life study. He has been criticized as over-optimistic, but his figures are worth something. I quote from a circular he issued that covers the status of oil shale in 1920 and gives the latest information on the subject.

> There are enormous deposits of oil shale in the United States. The shale contains a substance called "kerogen," which when heated is distilled into oil. By retorting this oil shale, oil is obtained in varying quantities. Tests in Colorado have given an average yield of about 20 gal. per ton of shale. However, there are deposits that yield 50 gal. per ton of shale and in some cases 90 gal. Shale in Canada has been tested that yields 120 to 130 gal. per ton of shale. The rich shale will be the first to be worked for commercial purposes. We have all kinds of shale in Colorado; enough to yield about 20,000,000,000 bbl. of oil, so far as we know. According to the best estimates of the United States Geological Survey, there is enough shale in southwestern Indiana to yield 100,000,000,000 bbl. of oil. New deposits have been discovered recently in California which are of considerable importance. In other words, shale will provide oil resources to last for many generations. We were all interested in shale oil during the war. The Government made some investigations and so did other organizations, but we must tackle the problem in earnest and learn the methods of working oil shale. We must create new methods. It must not be forgotten that to supply our automotive fuel needs, we must mine as much shale as we now mine coal. The development of this immense industry is a tremendous problem, but we shall have from 15 to 30 years in which to work it out. We should start right now, and learn how to retort the shale, so as to utilize the oil it contains.

At present such firms as the Standard Oil Co., the Ohio Cities Gas Co. and other large financial interests have bought a large number of shale properties and we have shale-oil plants operating on a commercial basis. The Catlin plant at Elko, Nev., has produced oil from shale at a price of $1.25 per bbl. of oil. That would be about 3 cents per gal., a great difference from 30 cents per gal. for gasoline. E. W. Hartman, president of the United States Producers Refining Co., which has bought about 1000 acres of oil land in California, estimates that his company can obtain shale oil for 65 cents per bbl., which is very much less than we are paying for crude oil in the Mid-Continent field. Plants are being erected throughout the West and commercial research is being carried out.

Even so, however, there is less enthusiasm over shale oil in this country than in England, in spite of the fact that they are having trouble there. They have rich shale deposits, but this shale contains sulphur. The problem for England is how to remove the sulphur and that is difficult. To solve it the University of Birmingham has obtained donations of not less than $625,000 through various oil companies in England to carry out research work on how to remove sulphur from shale. We have no such trouble in this country with the oil shale. Our trouble is that perhaps some interests will continue to advocate obtaining crude oil from South America and that we will neglect the production of shale oil in this country on a commercial basis. On the whole I can hardly do better than to quote verbatim the optimistic conclusion of Mr. Alderson.

> Close observers have known of the possibilities of oil shale for years, but not until the past year have laymen, investors, oil men, mining men and the large financial interests become awakened to the full import

of the subject and its great possibilities. The action of such strong financial organizations as the Union Oil Co. of California, the Pure Oil Co, the Ohio Cities Gas Co., the Carter Oil Co., the Standard Oil Co. and the Midwest Oil Co. in the United States; the Anglo-American Co. and the Anglo-Persian Oil Co. of London; and the Var Coal & Oil Co. of France, in acquiring land and investigating the method of treatment of oil shales, points unerringly to the early establishment of the industry on a commercially productive basis, so that the United States need have no apprehension whatever about its domestic supply of crude oil, virtually for all time.

THE DISCUSSION

W. G. CLARK:—With a mixture of alcohol, kerosene and benzol, what engine compression is used?

PROF. C. A. NORMAN: — Mixtures like that have been tried out by the London General Omnibus Co. The final compression used was, I think, about 120 lb.

MR. CLARK:—When you said that this mixture of alcohol, kerosene and benzol is superior to gasoline, did you mean that it is superior in the same engine?

PROFESSOR NORMAN:—The data I have seen do not cover this point explicitly, but my impression is that the same car and engine are meant.

MR. CLARK:—In a mixture such as that do the detrimental effects of benzol as regards the attacking of the metals still remain in the mixture, or does the mixture of these different fuels eliminate that effect?

PROFESSOR NORMAN:—I think that would have to be guarded against to some extent. Some of the effects are due to the water that is in the alcohol and the benzol. It is possible that the water would tend to separate out and that the corrosion would be reduced on that account; but, if the benzol is not pure, for instance, polymerization will occur and clog up the fuel passages.

A. F. MOYER:—Are not some of the substances such as benzol of great value for producing mixtures with lower grades of fuel? I have in mind a 3 to 1 kerosene-benzol mixture I tested. In the actual operation of the engine one could not distinguish the difference between that fuel and the ordinary low-test gasoline. The engine would start as well and run with about the same fuel consumption per horsepower-hour. If we could utilize some of the low-grade fuels by mixing benzol with them it would be a perfectly commercial proposition.

PROFESSOR NORMAN:—I think it would be a commercial proposition, but the question is whether benzol could be produced on a large scale. Only about 1,000,000 bbl. of benzol is available at present; I think it would not have a very great effect on the fuel situation generally. It might be an important consideration in the tractor situation. I think the tractor consumption of gasoline amounts to not more than 5,000,000 to 10,000,000 bbl. of gasoline per year.

MR. MOYER:—I understand that research work is being carried on in coking processes that will greatly increase the supply of light fuels from that source. The vapor pressure is the property of fuel that determines the quality of vapor-air mixtures. The vapor pressure of a mixture of liquids may be equal to the sum of the vapor pressures of the individual constituents. This may be true of dissimilar substances such as benzol and kerosene. We could mix with such fuels as benzol, alcohol, etc., large proportions of low-grade petroleum products and thereby increase our fuel supply.

PROFESSOR NORMAN:—The production of a greater quantity of benzol from coke is a simple matter of temperature. If the coking process is continued to very high temperatures, it results in a large quantity of permanent gas, some naphthalene and a very small quantity of oil; at lower temperatures various other products are obtained. I do not know what could be done in that respect. Much work has been done on this in England. As to vapor pressures, in many cases the amount of vapor tension can be increased by mixing in other substances. For instance, the vapor tension of benzol and alcohol together is considerably greater than the vapor tension of the two taken separately.

MR. CLARK:—Is not that also the reason for the advantage claimed for certain substances advocated as ingredients to put in fuel tanks in small quantities to increase the efficiency?

PROFESSOR NORMAN:—There is a patented substance of the General Motors Research Corporation that works in that way. What we desire is to increase the economy and the power of the engine by increasing the compression without introducing any undesirable feature. With kerosene, the engine compression is 60 lb. per sq. in.; with present-day gasoline the compression is 70 to 80 lb. per sq. in. Gasoline is becoming of worse quality continuously. It has been found that if about 3 per cent of anilin or iodine is added to gasoline fuel, the mixture prevents cylinder knock. The explanation is complicated. It is given in a paper[13] by Thomas Midgley, Jr., entitled Combustion of Fuels in Internal-Combustion Engines. Anilin or iodine can be mixed with gasoline to obtain higher compression and get better economy from the fuel. The question arises whether it is economical to produce enormous quantities of anilin to enable us to construct more efficient engines. My attitude is that we ought to construct an engine that will utilize the fuels as they are more efficiently. It may even be impossible to produce the enormous quantities of anilin we would need.

L. F. OVERHOLT:—How are alcohol and kerosene mixed to make them combine?

PROFESSOR NORMAN:—Kerosene and alcohol do not mix well. However, if about 7 or 8 per cent of benzol is first mixed with the alcohol, it acts as a binder when the kerosene is added.

DRY AND WET MIXTURES

I. L. JOHNSON:—In using kerosene and alcohol should the mixture be dry when it enters the cylinder or slightly wet? We believe that it should not be too wet, but that some dampness will give better results in actual horsepower.

PROFESSOR NORMAN: — There is some difference of opinion as to whether one should use a wet or a dry mixture. I believe in a dry mixture. If the air is heated, this has a tendency to reduce the power to some extent. The Bureau of Standards has made tests along this line. Keeping the air cool to allow the fuel to enter wet, gives more power; but, when driving on the road, the more the mixture that enters the engine is heated, the better the acceleration becomes. From the view-point of general reliability of the engine, freedom from carbonization trouble and crankcase dilution, it is better to run a dry mixture. We know that we get better acceleration from a dry mixture, even if we do not get as much power on block test; so, I am in favor of a dry mixture. It is believed in England that a dry mixture is the best.

MR. CLARK:—Maximum power is a thing we do not deal with or use in the automobile. Automobiles are overpowered. Dry mixtures are by far the best performing mixtures for automobile work. The tractor is a form of automotive apparatus in which maximum power is a

[13] See THE JOURNAL, December, 1920, p. 489.

(*Concluded on page* 203)

Relation Between Fluid Friction and Transmission Efficiency

By NEIL MACCOULL[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

THAT all of the variable factors of automobile friction-losses such as the quantity and viscosity of lubricants, the efficiency of worm-gearing and part-load modifications are not appreciated, is indicated by an examination of the literature on this subject which reveals a lack of necessary data. Experiments to determine the mechanical losses, including all friction losses between the working gases in the engine and the driving-wheels of the vehicle, are described and supplementary data are included from Professor Lockwood's experiments at Yale.

Three distinct possibilities for increasing the fuel economy of a motor vehicle are specified and enlarged upon, gearset experiments to secure and develop data for a four-speed gearset being then described and commented upon at length; photographs and charts illustrative of the equipment used and the resultant data are included. The effects of varying the speed under no-load and load conditions are studied, inclusive of mathematical analysis, and the efficiency of the gearset and noise measurements made in regard to it are discussed. The paper is then summarized.

ALTHOUGH means of minimizing thermal losses in motor-vehicle engines have received a certain amount of study, very little attention has been given to the mechanical-friction losses of the engine and the transmission system. Mechanical friction is usually thought of as a necessary evil, and has been dismissed without much further analysis. An examination of the literature on tests of automobile-friction losses shows, by a lack of certain data, that all the variables were not thoroughly appreciated. For instance, as data given later in this paper will show, the quantity and viscosity of the lubricants used have a pronounced effect on the magnitude of the losses; yet most experimenters do not take this into consideration, and few even mention data from which oil viscosities can be computed. Again, the elaborate experiments on the efficiency of an automobile worm-gear published by the Department of Scientific and Industrial Research, of Great Britain, failed to give data by which losses at other than full load can be estimated. In fact, most experiments are made at either full load or full speed, apparently unmindful of the fact that a motor vehicle operates only occasionally under such conditions.

The term "mechanical losses" as used here includes all friction losses between the working gases in the engine cylinders and the driving-wheels of the vehicle. The only "useful work" done by an engine and its transmission system on a level road is in overcoming the resistance of tires and wind-pressure. In reality, the tire resistance is a part of the complete transmission system, but it is not a mechanical part of that system. Therefore, a mechanical efficiency of 100 per cent would mean that the indicated power of the engine would be equal to the sum of the tire and wind-pressure resistances only. The magnitude of the useful force necessary to propel a typical touring car of 4500-lb. weight at various speeds on smooth level ground, in terms of drawbar pull or towing resistance, is shown below the datum line of Fig. 1. Above the datum line, the mechanical losses of the separate units of the car are shown in terms of propeller-shaft torque. The data are computed from experiments of Prof. E. H. Lockwood at Yale, and the experiments are described later in this paper. Cord tires pumped up to a pressure of 65 lb. per sq. in. were assumed. Fabric tires under the same conditions would have nearly double the resistance, and both would have considerably greater resistance with lower air-pressure.

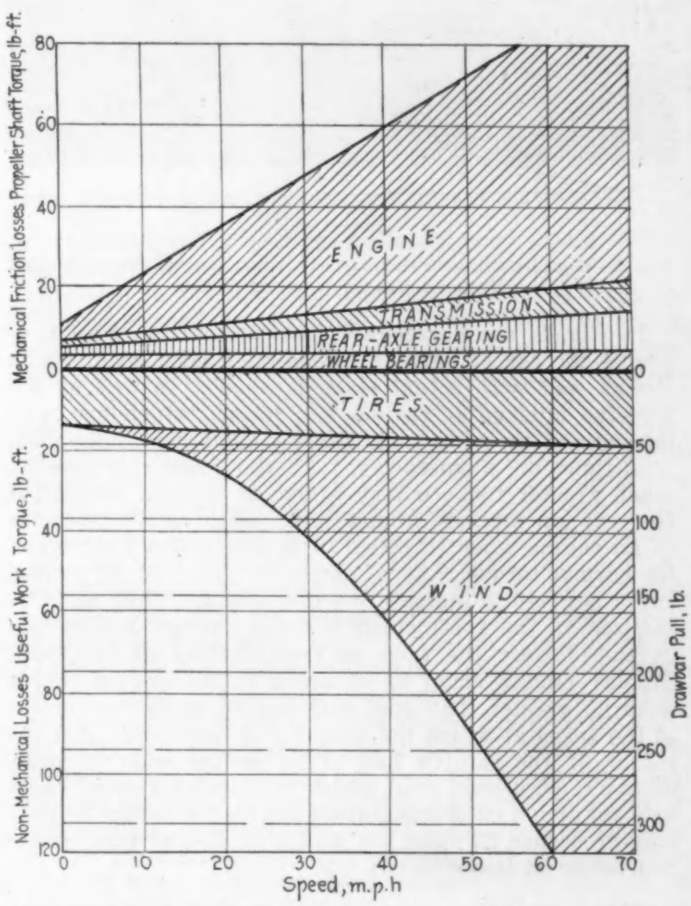


FIG. 1—DIAGRAM SHOWING THE MECHANICAL LOSSES IN A TOURING CAR WEIGHING 4500 LB. AND THE MAGNITUDE OF THE USEFUL FORCE NECESSARY TO PROPEL THE CAR AT VARIOUS SPEEDS

An examination of the items comprising the losses shown in Fig. 1 suggests three distinct possibilities for increasing the fuel economy of a moter vehicle.

(1) A suitable relation between gear-ratios and engine will reduce the well-known engine losses due to extensive throttling at average car speeds
(2) Reduction of vehicle weight
(3) Reduction of mechanical-friction losses

[1] M.S.A.E.—Automotive engineer, Texas Co., New York City.

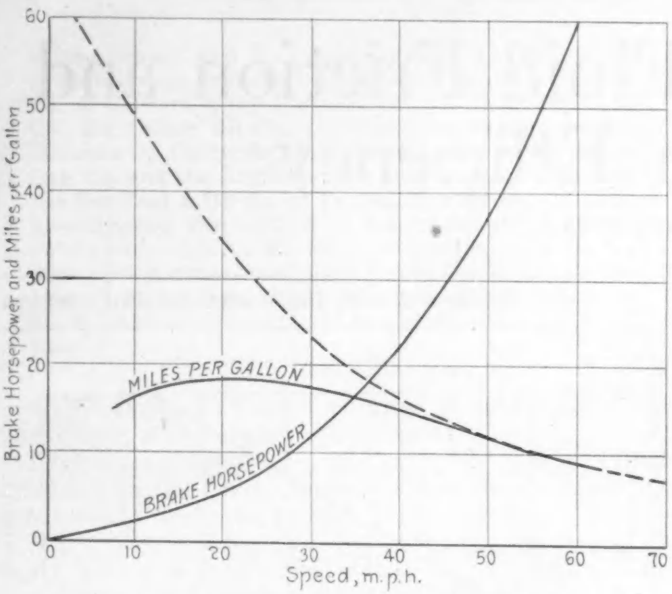


FIG. 2—HORSEPOWER AND GASOLINE-MILEAGE CURVES FOR A 4500-LB. TOURING CAR AT VARIOUS SPEEDS

In Fig. 2, the horsepower, calculated from Fig. 1, to propel the car at various speeds on a level road, which checks well with actual tests, is shown, as well as the gasoline mileage at various car speeds, which has been determined experimentally for a similar car under ideal conditions on a speedway. At the lower car speeds, much greater fuel-economy would be realized except for the very low mechanical and indicated thermal efficiencies of an engine when throttled to develop but a fraction of its normal torque. As a matter of interest, the dotted curve is given to indicate the fuel economy that could be realized if the fuel consumption per brake horsepower developed were the same at fractional as at full load. Similar results could be obtained if the engine power were no greater than just sufficient to drive the vehicle at the speed at which the economy is indicated. For instance, if the throttle had to be opened wide to make 25 m.p.h. on a level road, either because of a small rear-axle reduction or a small-sized engine, it would be possible to secure 28 miles per gallon of fuel at that speed, and better at lower speeds.

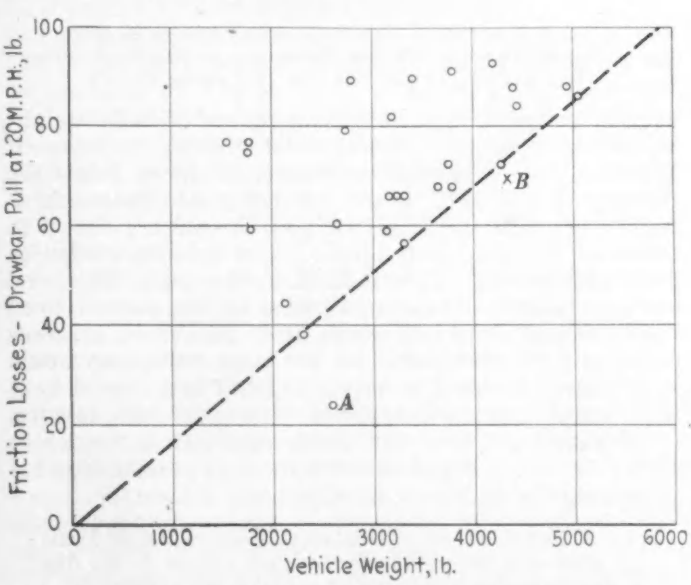


FIG. 3—ROLLING RESISTANCE OF VARIOUS CARS AS THEY WERE ACTUALLY RUN OVER THE ROAD

Fig. 3 shows some of Professor Lockwood's data in regard to the rolling resistance, excluding wind resistance, at 20 m.p.h., of various cars taken from the road in the actual condition in which they were run by their owners. The variation of resistance with weight is evident, as well as the superiority of some cars over others of the same weight. Notice the exceptionally low resistance of car *A*, which made 82 miles on 1 gal. of fuel on an official road test. Point *B* represents the car assumed in Figs. 1 and 2.

The question upon which it is attempted to focus attention here is, Why have some vehicles so much less frictional resistance than others of the same weight? If the distribution and cause of all these losses were known, it seems reasonable that all cars might be made with no greater resistance than those that fall on the dotted line, and even better might eventually result. Such data are food for much thought among those who wish to produce vehicles with really high fuel-economy. An analysis of these losses can be made only by isolating the individual units and examining each separately.

GEARSET EXPERIMENTS

Methods taken to secure and develop this information for a four-speed gearset, and some of the results secured, are described in this paper. The data are not at all complete because of lack of time, but it is believed that the general trend of the results, even though unchecked, will be of interest to the profession. The magnitude of the task is indicated by the fact that the six variables of gear-ratio, revolutions per minute, oil type, oil temperature, oil level, and load, were dealt with. No satisfactory method was available for separating the bearing losses from the gear losses and, to do so, separate bearing tests must be made. This investigation did not cover the results of varying the gear-pitch, tooth-shape and tooth hardness, or the very important feature of wear.

The two gearsets tested were standard four-speed frame-type Brown-Lipe truck transmissions, rated for 35 hp. at 1000 r.p.m. The construction and principal dimensions can be seen in Fig. 4 and the gear-ratios in Table 1. The gears are of 5-per cent nickel steel, case-hardened and of 6/8 pitch. Timken taper roller-bearings were used throughout. A sheet-metal case, for water or brine and ice mixtures to control the temperature, was placed around each gear case. Thermometers were located as shown, to measure the temperatures of the oils near the center of their masses.

TABLE 1—GEAR-RATIO OF THE GEARSET TESTED

Speed	Teeth of Engaging Gears	Total Reduction
Reverse	18-33—16-13—16-35	4.81
First	18-33—16-35	4.00
Second	18-33—21-30	2.62
Third	18-33—28-23	1.50
Fourth	....	1.00

APPARATUS LAYOUT

For the sake of greater accuracy, the friction losses were measured directly instead of being calculated as the difference between power input and output. For this purpose an unusual set-up was made in which two similar gearsets were bolted together rigidly with the propeller-shaft ends coupled together. Thus, if both units are in the same gear-ratio, the shafts *a a*, which are normally connected to the engine, both turn at the same speed, since the speed-reduction of one gearset will be

compensated for by a similar step-up in speed in the other. The unit consisting of both gearsets was suspended from each end on two ball bearings that acted as rollers, as shown in Figs. 4 and 5, and was free to swing or oscillate about the shaft centers. It is evident that, if the input and output torques are not equal, the difference between them will manifest itself as torque tending to rotate the unit; and the magnitude of this torque can be read directly on a spring-scale fastened on an arm bolted to the unit, which resists this torque. Since the speeds of the shafts transmitting power to and from the unit are equal, any difference between their torques will show directly the torque loss due to friction in the two gearsets. By measuring the losses directly in this way rather than by subtracting the power absorbed by the brake from the power of the engine, much greater accuracy was obtained, since errors of observation are normally large in comparison with the power losses involved.

Power was supplied by a 150-hp. Sprague cradle-dynamometer used as a motor, and the load was applied by a Froude hydraulic brake. These two units were coupled to the gearset unit by short lengths of shafting and semi-flexible couplings of the Clark type supplied by the I. H. Dexter Co. They were in reality thin chain-sprockets tied together by roller chains, and allowed enough flexibility to reduce very materially the labor of lining-up.

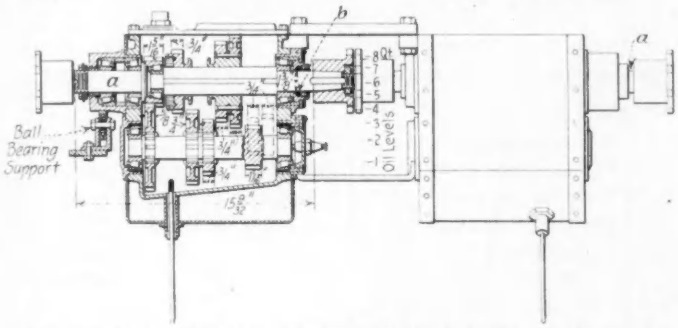


Fig. 4—Construction and Principal Dimensions of the Two Gearsets Tested

Figs. 5 and 6 show the set-up of all of the apparatus. On the end of the arm carrying the spring-scale for reading the power losses, a dashpot was improvised by suspending a weighted disc of metal in a pail of gear oil. At the other end of the arm, weights were suspended so as to counterbalance partially the weights of the scale and disc in the dashpot. The power losses for one gearset were assumed to be one-half the losses read. This involves a small error because the power input of the second gearset is not as great as that of the first, the difference being the power lost in the first, but it is too small to consider.

Test Routine

When first set up, the gearcases were filled with kerosene and run for a short time at low speed to wash out any chips or other foreign matter. After running only a few minutes, one of the bearings began to squeal and soon bound tightly enough to stall the motor, which was drawing only enough current to turn over at a speed of a few revolutions per minute. Reversing the motor loosened the bearings for a few turns only; the same squealing and binding then reoccurred. This was true whether the gears were in neutral, direct or in gear, and was not helped by backing off the bearing adjustment. All trouble ceased when the kerosene was drained and a few drops of light machine oil were run on the bearings, proving that roller bearings certainly must have a better lubricant than kerosene.

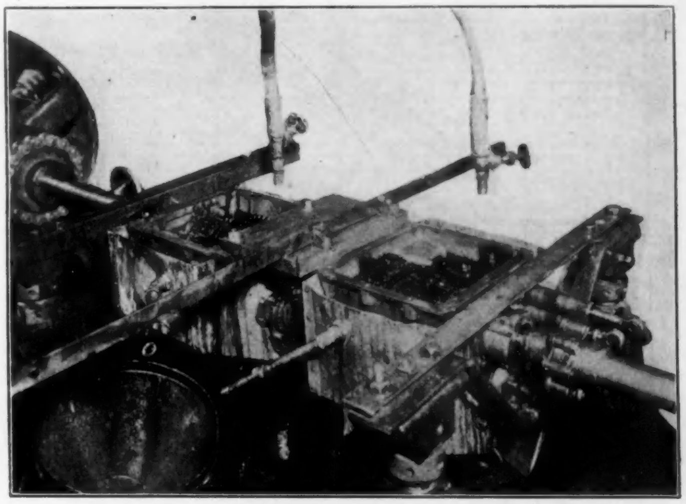


Fig. 5—The Two Gearsets as Arranged for Testing

It will be noticed that one gearset always runs in a direction opposite to normal. This reverses the action of the oil seal provided for the engine shaft, which consists of a helical groove cut in the bearing retainer where the engine shaft passes through. Simple as this seal is, it is so effective that oil seldom leaked through from the gearset running in the normal direction, while the other gearset leaked a steady stream. Advantage of this feature was taken in cleaning the gear cases when changing from one oil to another. After draining, they were filled with kerosene and run in one direction until there had been sufficient leakage at one seal, and then reversed for leakage at the other seal. This assured the removal of most of the oil from the space between the engine-shaft bearings. No trouble was experienced with binding bearings because of lubricating oil which dissolved in the kerosene. After draining the kerosene, the cases were dried and filled with the oil next to be tested, the gears were run first in one direction and then in the other to assure getting the new lubricant to all bearings, and then the oil was drained to the proper level. Normal oil-level represented 4 qt. in each case. The oil levels resulting from various quantities of oil are shown to scale in Fig. 4.

It was not easy to clean the gear cases even in this way after using greases, since the latter are almost in-

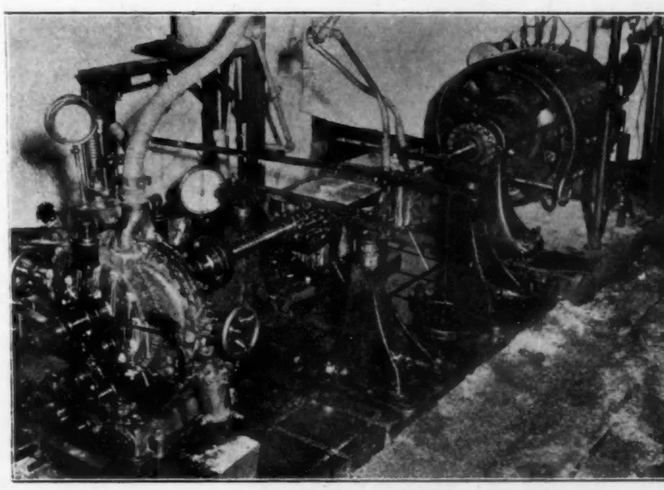


Fig. 6—General View of the Apparatus Employed in the Tests

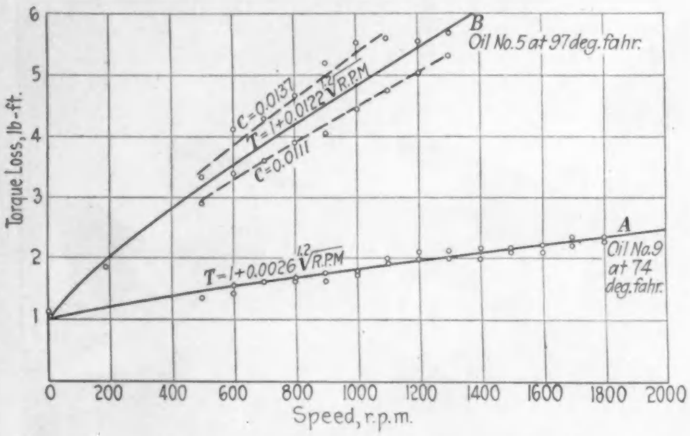


FIG. 7—CURVES SHOWING THE LOSSES AT DIFFERENT SPEEDS WHILE ACCELERATING AND DECELERATING

soluble and must be dug out of the corners. It is easy to believe that automobile operators would not be very thorough in cleaning out cases filled with old grease, and sediment and chips lying near the corners might be left to mix with new grease. This is a strong objection to the use of any grease that does not possess sufficient fluidity to drain out by itself.

TEST RESULTS

Except where specified, all runs were taken at 1000 r.p.m., second gear and with 1 gal. of oil in each gear-case. By taking readings of losses at different speeds while accelerating and again while decelerating, so that a whole series covered less than 1 min., it was possible to discount the effects of temperature changes because the oil temperature at the end of a series was but 1 or 2 deg. higher than at the start. As might be expected, the readings taken while accelerating are higher than while decelerating but, at low temperatures, with very viscous oils, the differences are greater than can be accounted for unless the temperature of the oil adjacent to the moving surfaces became heated locally above the normal temperature of the remainder of the oil. Most of the runs showed a fair agreement of accelerating and decelerating data as indicated by curve A in Fig. 7, and

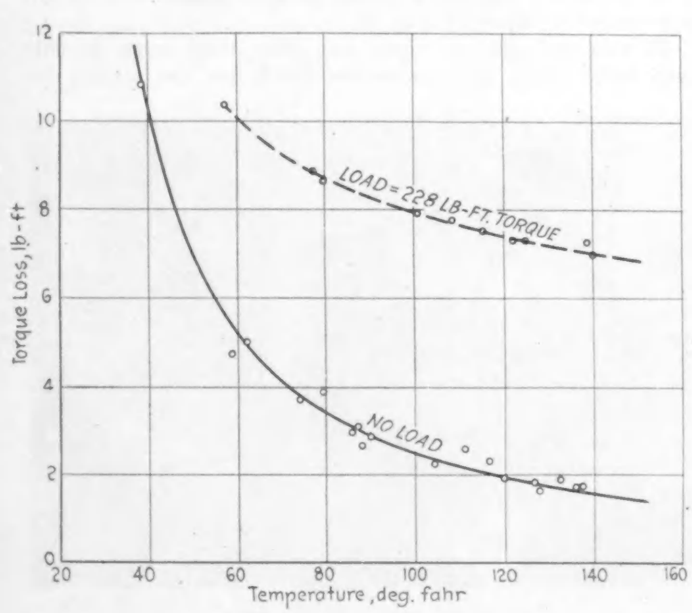


FIG. 8—TYPICAL DATA FOR A RUN WITH ONE OF THE OILS TESTED

an average was assumed as the true value. These curves followed an equation of the form:

$$F = K + C \sqrt[1.2]{(S)} \qquad (1)$$

where

C = a constant
F = friction loss in pound-feet of torque
K = a constant, varying with viscosity and oil level
S = speed in revolutions per minute

One of the most interesting results of these experiments was the discovery of the constant K, which is equivalent to a starting friction that must be overcome before motion begins and in addition to all losses varying with the fluid friction of the lubricating oil. It is not certain what the cause is for the existence of this starting friction, for one does not associate roller bearings with this characteristic of plain bearings. There is a possibility that it is due to the compression packing on the main shafts, shown at b in Fig. 4, that is used to prevent oil leakage, although this was not investigated. The constant C varies with the viscosity of the lubricating oil as will now be shown.

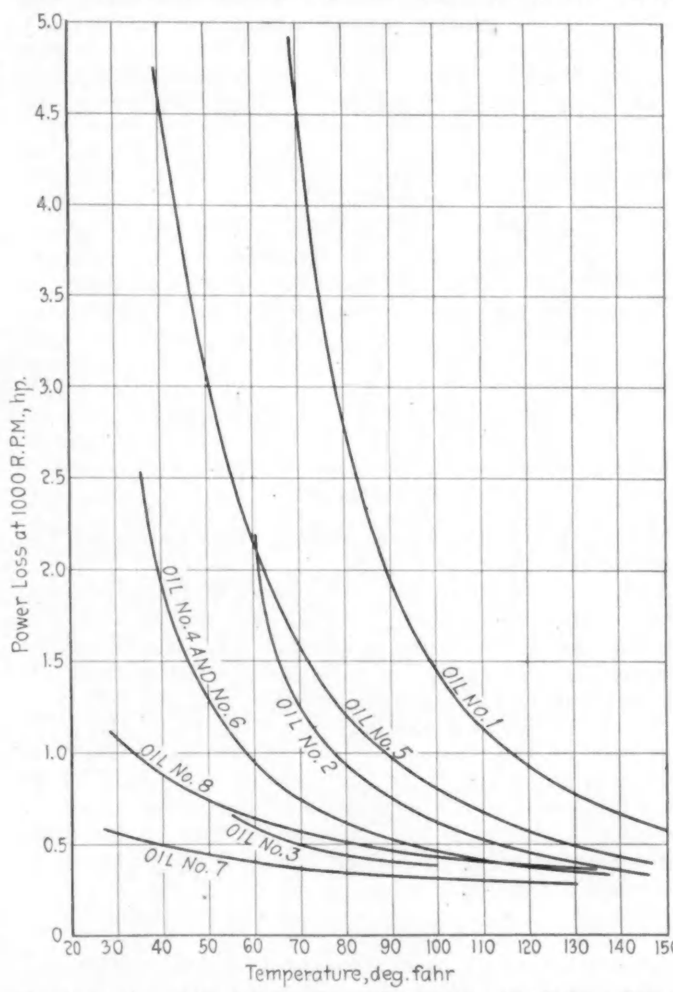


FIG. 9—A COMPOSITE CURVE OF THE CORRESPONDING NO-LOAD LOSSES FOR DIFFERENT LUBRICANTS EXPRESSED IN TERMS OF HORSEPOWER

To determine the effect of temperature changes, the lubricant was chilled by packing the jackets with crushed ice and calcium chloride. The time required was much longer than was expected, especially when the temperature of the lubricant neared the pour-point. In one instance, a temperature of 20 deg. fahr. below zero was maintained for nearly 3 hr., yet the oil temperature was lowered only to 29 deg. fahr. The first readings were

taken as soon as the motor speed was brought up to 1000 r.p.m. The motor was then stopped while the oil temperatures were read. The average reading of the thermometers in each gearcase was used in plotting the results. At the lower temperatures, the oil temperatures rose so rapidly at this speed that it was difficult to take readings with fair accuracy. Readings were taken in this way at intervals as the oil temperature rose. After a few such readings, the rise of temperature was hastened by

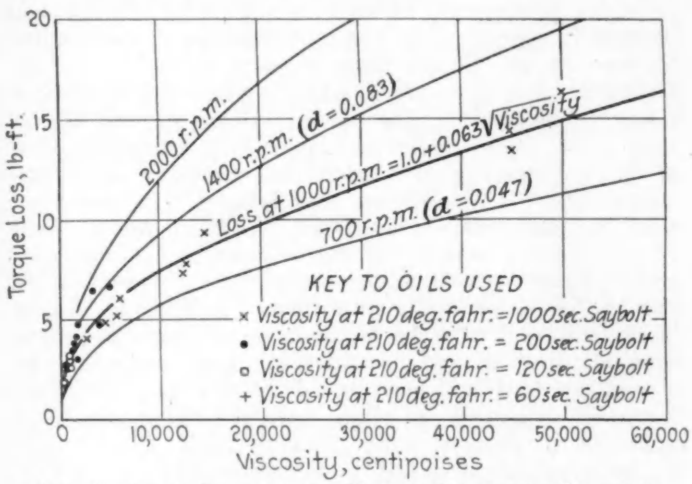


FIG. 10—CURVE SHOWING THE NO-LOAD LOSSES FOR DIFFERENT LUBRICANTS PLOTTED IN TERMS OF VISCOSITY

adding warm and then hot water to the jackets. Fig. 8 shows typical data from such runs for one oil, and Fig. 9 is a composite of the corresponding no-load losses found for different lubricants under the same conditions but expressed in terms of horsepower. It is evident how valueless any gear-efficiency tests may be without a record of either the oil or its temperature. Fig. 10 shows the data of Fig. 9 plotted in terms of the viscosity of the oils instead of their temperatures, which is really the information desired in such a test. The curve gives results that are useful in terms of a formula for any oil, since charts similar to Fig. 11 are available to show their temperature-viscosity relations. The heavy curve of Fig. 10 was plotted to an equation of the form:

$$F = K + D\sqrt{(V)} \qquad (2)$$

where

D = a constant
F = friction loss in pound-feet of torque at 1000 r.p.m.
K = a constant
V = viscosity in centipoises

The constant K seems to be the same as that appearing in equation (1), although one would expect it to vary with the number of revolutions per minute. The variation of the constant D with different oil-levels will be shown later.

The losses with oil No. 5 are consistently higher for corresponding viscosities than those of the other oils. It is believed that this was due to the presence in the pocket between the engine-shaft bearings of some of the very viscous oil, No. 1, that had been tested just previously. This would be a likely source of error if the washing with kerosene were not complete. The curves shown as light lines in Fig. 10 were computed from equations (1) and (2) for a number of revolutions per minute other than the experimental readings at 1000 r.p.m. Equation (2) was used to correct much of the following data to equivalent readings at some one temperature,

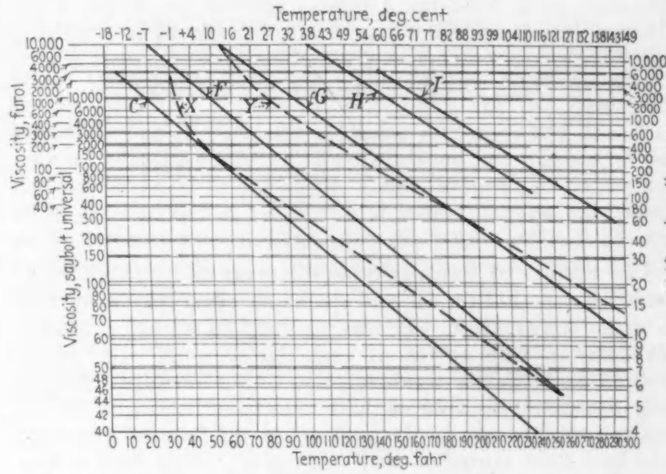


FIG. 11—TEMPERATURE-VISCOSITY RELATIONS OF A NUMBER OF LUBRICATING OILS

since the oil temperature varied somewhat during any series of runs taking much time. Equations (1) and (2) can be combined into an equation of the form

$$F = K + [D\sqrt{(V)}]\,.\,[\sqrt[1.2]{(S)}] \qquad (3)$$

where

D = a constant
F = friction loss in pound-feet of torque at 1000 r.p.m.
K = a constant affected by the oil level
S = speed in revolutions per minute
V = viscosity in centipoises

The effect on the power losses at different levels was much less than expected. Experiments[2] made in

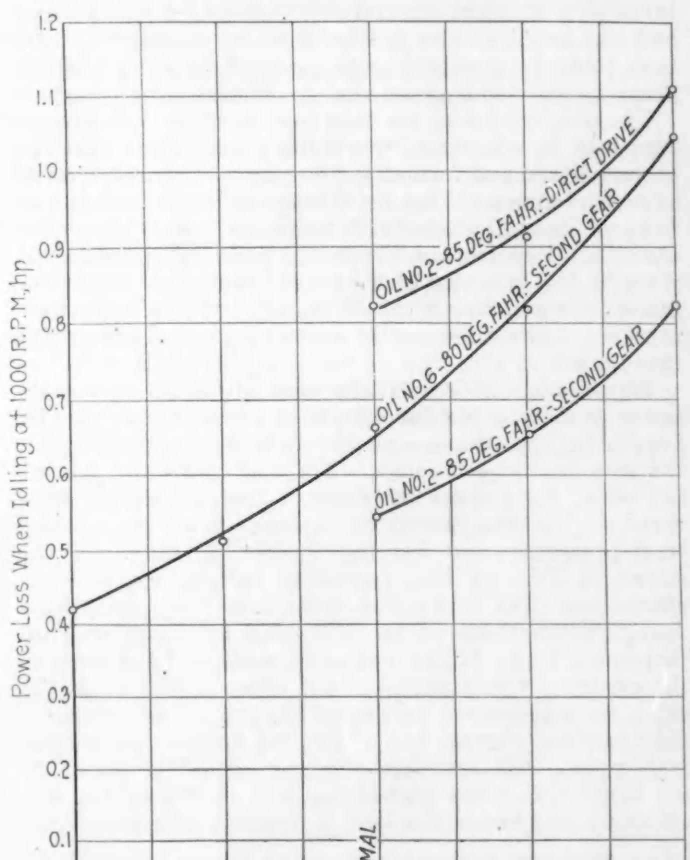


FIG. 12—CURVES SHOWING THE GENERAL RESULTS OF THE TESTS

[2] See Report of National Physical Laboratory for 1913-1914, p. 101.

England with a 32-hp. Leyland gearset on direct drive showed losses at 950 r.p.m. that are stated in Table 2.

TABLE 2—OIL LEVELS AND POWER LOSSES

Oil Level	Power Loss, hp.
¼	0.80
½	1.92
¾	3.20
Full	8.30

The results of our experiments were of the nature of those shown in Fig. 12 and failed to show anything like as great a variation. It was difficult to secure concordant data in this series of runs because all oils tested frothed up with air bubbles after a few minutes of running so that the volume was increased materially. It was not uncommon to drain 6 qt. of oil from a gearcase that had been supplied with only 4 qt. The torque loss recorded after all oil was drained from the gearcases consists of the constant loss K plus the viscous losses of the bearings due to the presence of a certain quantity of oil that clung to them. It is interesting to note here that the losses in direct drive are greater than in second gear for a given *engine* speed, although the reverse is true for a given *car* speed. Other experiments, such as those of Fig. 13, at a speed of 1175 r.p.m., showed that the no-load losses were lowest on first gear and increased regularly to a maximum on direct drive.

Losses Due to Load

So far, all losses given occurred while idling. While transmitting power, additional losses occur which are indicated in Fig. 14. All our experiments indicated that there is a straight-line relation between friction losses and load as shown also in Fig. 13 where similar data have been taken from experiments reported for an automobile gearset,[3] and for a steam turbine double-reduction gear.[4]

The intersection of the load line with the ordinate for zero load is, of course, the idling friction loss that has been analyzed and formulated during the preceding study of no-load losses. What determines the slope of this line, however, is not satisfactorily explained and is somewhat a matter of conjecture. It seems to be influenced somewhat by the viscosity of the oil, as indicated by the distance between the curves of Fig. 8. If the slope were constant, these lines would be the same distance apart throughout.

The number of revolutions per minute of the gears seems to have a similar effect, as is shown in Fig. 14, suggesting that the greater the number of revolutions is, the less the slope becomes. The gear-ratio also has its influence; the greater the ratio is, the greater the slope becomes, but this would be expected from the greater tooth-pressures and bearing loads. Light lines are shown in Fig. 14 that represent various transmission efficiencies. The load curves cross such lines, giving the usual characteristic of an increasing efficiency with an increasing load. If the load were continued indefinitely, the efficiency would approach but never wholly equal the efficiency represented by one of these constant-efficiency lines running parallel to it. For the curve representing 1000 r.p.m., this optimum efficiency would be about 98 per cent. Thus, the higher the load is, the higher the efficiency will be until a load is reached where the load curve ceases to be straight and becomes concave upward, a point not reached in these experiments.

Since the efficiency increases with load, it is interesting to know how high a load the gears can carry. When delivering 43.3 hp. at 1000 r.p.m., which represents 227 lb-ft. of torque, the tooth load was over 4000 lb. per lineal in. of face-width and the static fiber-stress was about 67,000 lb. per sq. in. This stress was figured from a formula given by Prof. G. H. Marx as a result of his experiments.[5] Over 50 hp. was carried several times with no signs of distress, which corresponds to a tooth load of 4800 lb. per lineal in. and a fiber stress of over 80,000 lb. per sq. in. Static tests show a breaking load of 18,000 lb. on a ¾-in. face, which corresponds to a fiber stress of 305,000 lb. per sq. in. These figures are so very much higher than experienced in other branches of the engineering profession that they are especially noteworthy. It is probable that failure by abrasion or wear will occur before breakage, but there was no sign of abrasion in these tests. Experiments on the wear of gears loaded to 3668 lb. per lineal in. have been made and the results recently published.[6] In making use of these figures, it must be borne in mind that these loads were all uniform and not fluctuating as would be the case if the drive had been by a four or even a six-cylinder gasoline engine, in which case a similar maximum would result from a lower average load. Notice that the optimum efficiency will be approached at all loads by a reduction of the no-load losses. If there were no losses at no load, the efficiency would remain constant and equal to the optimum at all loads.

Efficiency of the Gearset

When referring to gearset efficiency it is only fair to talk of the efficiency at the loads experienced in operation. This has been done for level-road conditions in Fig. 15, taking the loads transmitted from Fig. 1 as the sum of the wind, tire, wheel-bearing and rear-axle losses at various speeds.

The curves for direct drive at different temperatures are of particular interest because of showing lower efficiency, with the "heavy" gear-oils now popular, than is usually thought of except when in gear. When a vehicle is run only a few miles between stops during cold weather, the oil does not have time to heat up much and may easily be at a temperature no higher than 60 deg. fahr. The shape of these curves at first seems odd, but is explained by the fact that at low speeds the losses increase more rapidly than the load, accounting for the falling efficiency with increased car speed. The phase of rising efficiency with increasing car speed results when the load increases faster than the losses. In addition to the curve given for second-gear efficiency, a dotted curve is given for the same losses, while carrying the full rated torque of the gearset. Since gears are rarely used except with wide-open throttle when climbing hills, this represents more nearly the actual efficiency obtained than the corresponding curve for level-road conditions. A similar increase of efficiency results for direct drive when climbing grades requiring full throttle, but the level-road conditions more nearly represent average conditions.

Noise Measurements

Noise is such an important factor in the transmission of power by gears that an attempt was made to measure it and determine how it is influenced by the lubricant used. After consulting several authorities, the following apparatus was suggested by the Western Electric Co., which was also kind enough to lend it. A microphone

[3] See *Mechanical Engineering*, November, 1920, p. 613.

[4] See *Journal of the American Institute of Electrical Engineers*, September, 1921, p. 724.

[5] See *Transactions of the American Society of Mechanical Engineers*, vol. 37, p. 520.

[6] See *Automotive Industries*, Nov. 3, 1921, p. 865.

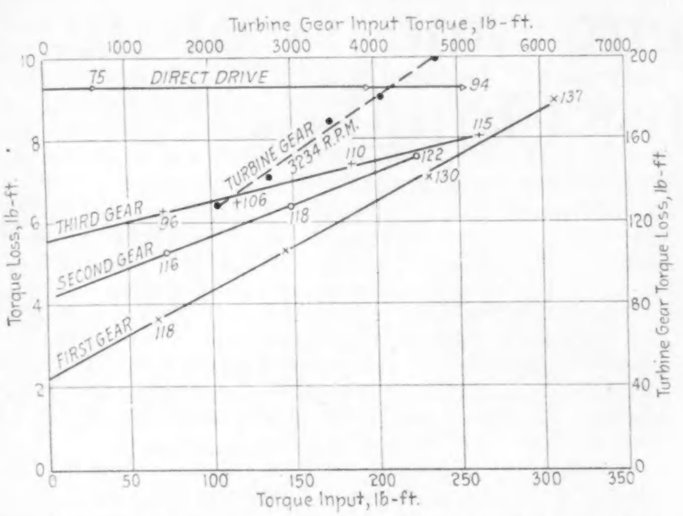


FIG. 13—RELATION BETWEEN THE TORQUE INPUT AND LOSS IS A MINIMUM ON THE FIRST GEAR AND A MAXIMUM ON THE DIRECT DRIVE

The Figures Given on the Curves Are the Oil Temperatures

of the inertia type, without a diaphragm, was connected in series with a single cell of storage battery and the heating coil of a thermocouple, the thermocouple itself being connected directly to a direct-current microammeter. With the microphone button in contact with the outside of the gearcase, the microammeter pointer gave a reading that was recorded as a measure of the energy of vibration of the case, and was assumed to be a measure of the noise produced by this vibration. As slightly dif-

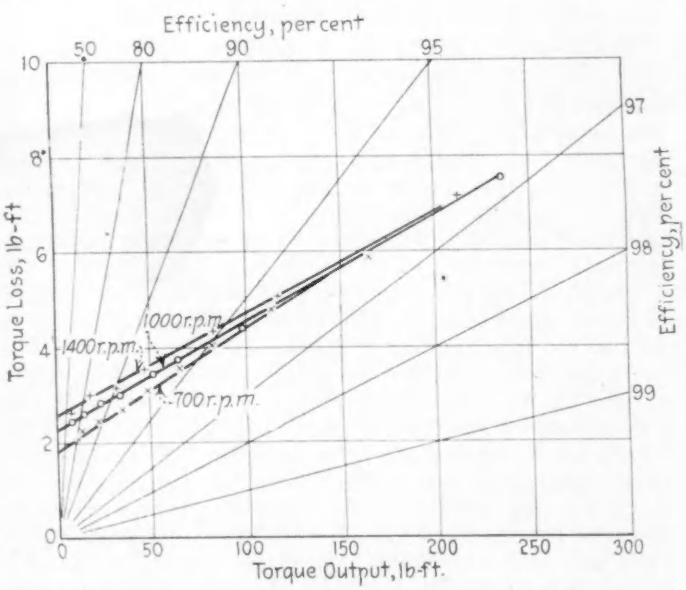


FIG. 14—LOSSES WHEN TRANSMITTING POWER AT VARIOUS SPEEDS

ferent readings resulted from contact with different parts of the case, contact was made at approximately the same point, at a corner, for all subsequent readings. Fig. 16 shows the results on direct drive and also on second gear. The pronounced crest of these curves, when one would expect them to continue upward, indicates that the microphone was not adapted to periods of vibration as high as those experienced. A change in the microphone was made but this was not much of an improvement. It is clear that further development will be necessary to make this apparatus useful, and there is little doubt that this can be done.

It has been shown that friction losses in a gearset consist of two distinct types; (*a*) those existing while idling or transmitting no power and (*b*) additional losses while transmitting power. The former were shown to be the sum of a constant and a factor for the fluid friction that varies with the viscosity and quantity of oil as well as with the number of revolutions per minute of the gears. When it is desirable, these factors can be formulated for a gearset so that the losses can be calculated with reasonable precision for all combinations of the variables involved. It has been shown also that an appreciable increase in efficiency will result by lowering the viscosity of the oil, particularly when the gearset is used for direct drive on a level road. Recommendations to use oils of low viscosity cannot yet be made, however, because of insufficient knowledge of the rate of wear and

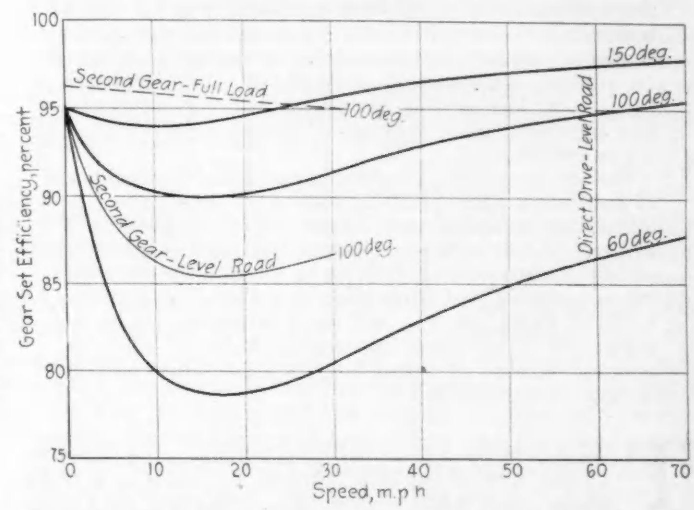


FIG. 15—THE EFFICIENCY OF THE GEARSET AT VARIOUS GEAR SPEEDS

The Figures at the Ends of the Curves Indicate the Oil Temperatures

volume of noise resulting from their use. It is doubtful if there will be any noticeable increase in the wear of an automobile gearset if an oil similar to a heavy motor oil be used, particularly since these gears are not used continually. The De Dion-Bouton trucks have made a very successful use of such an oil for their gearsets.

The data that have been given here are very suggestive for further analytical study, in regard to both gearsets and other parts of the power system of a motor vehicle. Time thus taken promises well to increase the efficiency of motor-vehicle transportation and reduce its cost, as well as to make our fuel resources last longer.

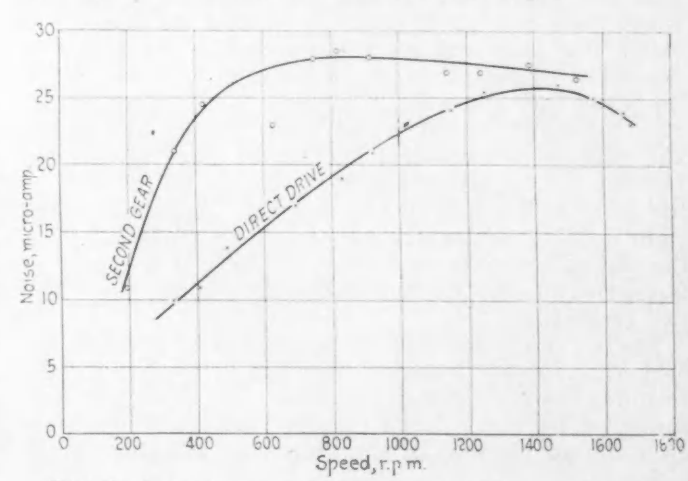


FIG. 16—RESULTS OF THE MEASUREMENT OF NOISE AT VARIOUS SPEEDS

The Past, Present and Future of the Motor-Omnibus

By Walter Jackson [1]

Annual Meeting Paper

AFTER outlining motor-bus history and relating how the introduction of mechanical and electrical propulsion on rails relegated horse-buses to the background, the author states that electric-railway construction is at a standstill and that the present demand for additional transportation facilities is being met by motor-buses that often are operated by individuals; presents railway statistics and comparative comment on jitneys, cross-country motor-buses and supplementary motor-bus service by electric-railway companies; and mentions many influential factors concerning motor-bus utilization.

Future motor-bus considerations include discussions of fare rates and operating expenses. The author believes that a comparison of the true cost of electric-railway versus motor-bus service has been obscured by certain factors having nothing to do with the engineering aspects of the situation, and that the economic fields of these services will be determined by the coordination of all mass transportation under one management instead of permitting indiscriminate and destructive competition.

THE writer on steam turbines seldom fails to refer to the time of the late Hero of Alexandria, a trifle more than 2000 years ago, and one who presents a paper on the road transportation of passengers must face the temptation of dragging forth the ghosts of Egyptian sledges, Roman chariots and English stage-coaches; but I will put the pleasing provocation by and plunge at once into a period no further back than that of our great-grandfathers. In the decade of 1830-1840 some serious and creditable efforts were made to produce a trackless, self-propelled vehicle. Indeed, as early as 1828 Sir Goldworthy Gurney's steam coach was making the 9 miles between Gloucester and Cheltenham in 45 to 55 min. Three years later the Ogle-Summers steam carriage was fleeting along the highways at 30 to 35 m.p.h., utilizing a modern boiler-pressure of 250 lb. per sq. in. Inventor after inventor came into the field within the next few years but, through the influence of the railroads, there was placed upon the statutes the absurd provision that each and every steam engine operated over the public highways should be preceded by a man carrying a red flag, at a walk, of course. The rate of locomotion, ironically termed "speed," was limited to 4 m.p.h., and railroad shareholders and horses were saved from fainting fits by permitting such vehicles to run only in the darkling hours of 10 p.m. to 6 a.m. College debating clubs may still argue whether legislation really can block the bus of progress very long, but here is a record of legislative obstruction that proved effective for more than two generations.

The net result was that, both here and in England, the field of passenger transport was left to the steam railroad and the horse-drawn omnibus. The latter was first succeeded by horse-drawn railway cars, for those were decidedly not the days of smooth paving, and then by the cable and the electric railways. For a time, it seemed that the electric railway would become the sole means of public-utility transport in city and suburban areas but, after two frenzied decades of expansion, it was seen that while electric traction is technically right there are plenty of places where it is financially wrong.

It would not be fair to criticize the old-timers too severely for the construction of uneconomic lines. They knew no other form of mechanical propulsion that would relieve them of the great cost of power-stations, substations, distribution systems and other rooted structures that go with the humblest electric railway. When electric-railway building was at its peak, the gasoline vehicle was in its first stages. The electric-traction men were not in the same position as the horse-drawn-omnibus operators of London who had to seek something faster and better without recourse to the rail. They refused to indulge in watchful waiting, but blithely went on to build thousands of miles of track through districts that did not produce enough business to meet operating expenses alone.

The Present

There was 47,941 miles of electric single trackage in the United States in 1919. In 1920 the mileage showed a decrease for the first time in the history of the industry, being 47,705 miles or a loss of 236 miles. The figures for 1921 may show a still greater loss. These declines are due to the deliberate abandonment of non-paying lines, principally of systems in receivership that are not compelled to continue to observe original franchise stipulations.

In cities so large as Bridgeport, Conn., and Des Moines, Iowa, we have seen extended periods of idleness on the part of the local traction systems. In the one case it was the hope of the traction company to compel the absolute elimination of jitney competition; in the other there was a desperate effort to secure a higher rate of fare. Like scenes are being enacted in other cities. One would not expect sane communities to prefer to exchange even a fairly reliable street railway under one corporate management for the uncertain, hard-to-please but far from coy jitney man. Yet they have shown themselves willing to put up with atrocious jitney operation for weeks and months rather than submit to the demands of the street railway. In short, the lack of good-will toward the electric railway blinds the community to settling its transportation problem upon the commonsense basis of all mass transportation in a community, regardless of the manner of propulsion, being under a central, coordinated management. So far, some electric-railway companies have not seen their opportunity to absorb unto themselves whatever special advantages the bus has for attracting traffic and reducing the operating costs of certain classes of service. They have actually given the impression by their antagonistic attitude that the field of the motor-omnibus is greater than it really is on the basis of present-day development, and they are encouraging the fol-

[1] Consulting engineer, Mt. Vernon, N. Y.

mation of motor-bus companies whose promoters seem very much in the dark as to the requirements of an exacting public.

It is significant that, while no important city has given up its railway system to change to the jitney-bus, the substitution of motor-buses for the cross-country trolley-car seems to be meeting with public favor. This class of trolley line usually has a single track, which handicaps its schedules; and, as most of its former patrons own motor-cars, the clientele tends to decrease year by year. Besides, the very advent of improved roads is a bane to this class of trolley in another direction, namely, that of re-alignment to new paving levels. Few such railways can afford to get out of the dirt and into the paving; so, they quit. The abandonment of several hundred miles of track by the Eastern Massachusetts Street Railway Co. alone is a forerunner of what other railways with cross-country lines on public highways are facing.

The development of both electric and steam railways in this Country has been on such a grandiose scale that one would hardly expect to find any community of considerable size without transportation service. Nevertheless, there has been already an imposing development of motor-bus transportation in non-competitive districts. Out of a city like Poughkeepsie, N. Y., for example, a number of individually owned motor-bus enterprises are operated which tap territory without railway service of any kind. There are literally thousands of one-man services of this kind that are performing a most valuable function. They produce a living for men who are willing to work 12 to 16 hr. per day, but would not do for companies from whom the community would demand better vehicles and more frequent service. There must be some deep-rooted belief that individuals in the public-transportation field are deserving fellows entitled to get away with anything; whereas, company organization at once implies that there are great profits for somebody somewhere, this implication meaning higher standards and higher taxes.

Jitney Competition

So far as jitney operation is concerned, that is here today, gone tomorrow and back again day after tomorrow. Endless State and municipal measures have been passed at the behest of both the railways and the public and, I may add, even at the behest of jitney men who have achieved the status of a vested interest and want protection against later comers. But much of this legislation seems to fall to the ground whenever the local street-railway company and the administration disagree. One day sees all the second-hand cars in town soliciting patronage, usually at a lower fare. The news travels and a hegira sets in toward the new jitney Medin. Thus, in the recent Des Moines trouble jitneys thrown out of Connecticut actually were driven overland to Iowa to obtain their share of the abnormal patronage.

Overland Motor-Buses

It has been more difficult to regulate the competitive overland motor-bus than the city jitney. The exclusive franchises that electric railways lean upon in municipalities do not apply to the country, where the electric railway may be a blend of city, highway and right-of-way operation. Often enough, the buses do not parallel the railway all the way but only in part. If they reach, in addition, off-side districts not served by the railway, it is hard for a State commission to say whether the proposed bus-route is entitled to a certificate of convenience and necessity. Most of the overland-bus companies, those in California and Washington, for example, charge lower fares than the railways, but the chief reason for their getting the business seems to be that they come closer to the patrons' origin and destination than the railways. In California, particularly, the delights of the climate are a strong temptation to outdoor riding.

As already hinted, the only curb on these cross-country or overland-bus operators is that they must in a growing number of States like Connecticut, New York, Pennsylvania, Illinois, New Jersey, California and Washington obtain certificates of convenience and necessity. This curb is of varying degrees of value, dependent upon the viewpoint of the commission. In one case the Illinois commission granted a certificate permitting competition against an electric railway because the latter had not met the commission's ideas of a proper standard of service; but the same commission refused a certificate to another applicant who wanted to compete with an electric railway giving satisfactory service. Commissions are inclined to give certificates in cases where a large part of the run will not be in competitive territory; and in competitive territory they may grant operating rights because of the lower fare offered.

Motor-Bus Legislation

The latest motor-bus legislation in which both city and country operation are placed under the State commission is that of Connecticut and of New Jersey. In the latter State, however, the commission exercises no control over operators who had regular routes before the time of the passage of the act, March 15, 1921. The question now before the courts is whether this exception constitutes a vested or property right that can be transferred to a successor. In the first case brought up the Board of Public Utility Commissioners granted this succession right to one Carl A. Becker, but the Public Service Railway Co. within whose area Becker operates has appealed the case. The point made by the commissioners was that the bus operators active at the time of the act had been regulated already as to number and routes by the local municipalities, and that they were therefore, presumably, fulfilling a work of convenience and necessity. Under their conception of the law entirely new petitioners can apply to them for routes, provided they have obtained approval previously from the local governments.

The cities of Connecticut never undertook to license public-utility vehicles; so the new legislation did not deprive them of any powers theretofore exercised. All that a jitney operator needed was the nominal State license for a public-utility vehicle, and all the regulation he endured was what the police chose to exact, as was evident particularly at Bridgeport. Theoretically, the Connecticut Public Utilities Commission is not obliged to pay much attention to what the different cities may desire, but practically it is under this obligation. In the city of Hartford, for example, the elimination of the jitney met with general approval. Contrariwise, the large working population of Bridgeport was bitterly opposed to paying a 10-cent fare on the cars in view of the fact that it had thitherto had a 5-cent fare on the jitney-buses. Preceding the passage of the State law, the Bridgeport council had agreed to relegate the buses to streets on which there were no car tracks, so far as that was physically possible. Despite this handicap the buses continued to get most of the traffic. When the State commission endeavored to put these jitneys out of business the latter adopted one subterfuge after another, such as accepting tickets from alleged club-members, besides securing stays from the courts. The commission itself, recognizing the hardship of a 10-cent fare, has ordered

lately a 5-cent short-ride fare and threatened to grant additional bus licenses if the electric railway does not give satisfactory rates and service.

I have gone into these nearby situations at some length to indicate that, while the regulatory bodies are gradually assuming control of motor-bus operation, it does not follow that the electric railways can afford to show indifference to the public. The people will find some way of getting what they want, sooner or later. It seems incredible that the electric railways themselves have been among the opponents of legislation that would grant the common carrier under discussion the right to run motor-buses. They actually feared that such recognition of the transportation usefulness of the motor-bus would make all of their own precious investments passé. This was topsy-turvy reasoning. The bus did not need this legislation to prove what it can do. Thus far not more than a score or so of our 800 to 900 operating railway companies have undertaken motor-bus operation, but even these few pioneers give a clue to some of the valuable results that can be attained with the motor-bus. One large city railway company has installed buses over a poorly traveled route to save the expense of retracking and repaving; another has given up a dangerous run along a steep river-bank to follow a shorter line on the highway; a third has cut down the losses on a roundabout electric railway by offering a shorter faster alternative bus route; a fourth has found that a bus-line makes it unnecessary to disturb a cherished public park; a fifth finds the bus the least costly medium for tieing together two important rail-routes; a sixth has made one loop out of two former trackways; and several others have found the bus a most desirable vehicle to ward off the cost of track extensions until new business justifies the old burdens.

We are all familiar with the splendid organization of the Fifth Avenue Coach Co., New York City, that combines both technical and sales leadership in its work. But this company, like the other double-deck bus operators in Detroit and Chicago, is doing a work somewhat apart from the usual organization that is responsible for all the mass transportation of the community.

Summarizing the present situation as to the motor-bus, we have the unreliable competitive jitney; the rapidly growing cross-country bus, sometimes competitive and sometimes creative; the beginnings of motor-bus operation by electric railways; the de luxe double-decker; and, finally, the "on call" motor-buses and char-a-bancs that may some day achieve the same widespread popularity they have attained in England.

The Future

Will the city and suburban electric-railway disappear altogether and the steam railroad be discontinued in part; or, will the increase in motor-buses be due more to the creation of new business because of their unlimited flexibility? The general public, unfamiliar with the cost of either mode of propulsion, cannot be blamed for thinking that the trolley-car is doomed when it observes the jitney charging half the fare and making 50 per cent greater speed; but the automotive engineer can be blamed if he fails to see that these two forms of transportation are not compared so easily as that.

The electric railway of today is the product of two generations of corporate life. During those generations it has accumulated a number of unwholesome factors that place it at a disadvantage in competition, entirely aside from the question of engineering merit. There is, for example, the fundamental franchise obligation that a certain amount of service must be given regardless of traffic, an obligation from which the jitney is almost or entirely free. There is the paving obligation from which the very jitney that runs over that paving is free. There is that host of taxes on costly buildings and land, on income, on the corporate form, sometimes even on trolley-poles or cars, from which the jitney suffers next to nothing. There is the curse of the same fare regardless of the length of the ride, while the jitney travels no farther than the fare will cover.

These are some of the burdens for which the railways themselves are not responsible to any degree, and they are burdens that would be paralleled in the long run by any regularly organized motor-bus company. The Fifth Avenue Coach Co. is not only the oldest and largest motor-bus organization in the United States, but it is the one that has gathered unto itself the largest tax-bill in proportion to earnings. And the gallonage tax is yet to come! Since these are burdens imposed by the State, they will become equalized in time; so they present no really great danger for the older utility. In truth, the burdens that the electric railway has accumulated without the help of government are far greater. If these are not shaken off or greatly reduced in weight, the motor-bus in independent well-monied hands will prove a real danger and supplanter in many of the smaller and medium-sized communities. First of all, the failure in the past to set aside amortization and depreciation funds to care for advances in the art has led to excessive replacement-needs at this time. Many companies are compelled to continue to operate with obsolete equipment because they cannot borrow the money for efficient apparatus, thus suffering much higher operating costs than the actual state of the art makes possible.

Rates of Fare

In the second place, in seeking a rate of fare that will restore their credit, electric railways have valued their property on a "reproduction-cost-new" basis and then sought also a war-time rate of return on this valuation. The consequence, in a number of cases, has been that the resultant fare required is so high as to frighten off an appreciable proportion of the traffic. This brings us to the vital question, Have electric-railway fares reached a point where the motor-bus can compete against and supplant the electric railway? I say without hesitation that any small-city electric-railway charging a 10-cent fare today is absolutely vulnerable to such competition, should the State allow a capably organized company to come in. There are some two score communities of that character charging a flat fare of 10 cents, and between 40 and 50 cities or towns charging a 10-cent cash fare and 6 to 9 cents for a ticket.

The railways in 70 to 80 communities charging 8 and 9-cent fares are also in danger, provided the length of route is within 3.0 to 3.5 miles. The 7-cent and 6-cent street-railways hardly could be touched by a motor-bus company so long as both had the same scheme of charging one fare regardless of the length of ride; but, if the motor-bus operators were wise enough to do business only on a distance-fare basis from the start, they would be able to begin at a 5-cent minimum for say 1 mile. Therefore, it will be seen that unless the electric railways in such districts are willing to write down their valuations as remorselessly as a merchant writes down his outof-date stock, they will not be saved by their inherently lower operating expenses. Here I may be taken up short by the over-enthusiastic bus-advocate who does not like

that last phrase about "inherently lower operating expenses." Nevertheless, it is true.

Motor-Bus Expense

It has been my work to analyze a great variety of motor-bus expenses, both real and theoretical. The real set-ups of actual expenses have been chiefly in Great Britain, where the motor-bus is a valuable and important part of the mass-transportation system and is almost always in railway hands. Although the basic costs differ materially from ours in at least the item of fuel, we know that they are based on actual and not theoretical conditions. When we look for the corresponding items in cost set-ups in this Country we find, with few exceptions, that a considerable number of items have been overlooked. For example, many of the estimates show a cost of 1 cent per seat-mile, whereas inclusion of all legitimate items in company operation would bring the cost to 1.5 and even 2.0 cents per seat-mile. The accounts of electric railways operating motor-buses confirm this estimate. Double-deck buses would be somewhat cheaper, of course, on the seat-mile basis. On the basis of the few well-kept accounts available in the United States it would seem that a 10-cent fare is the right fare for high-grade motor-bus service covering rides in excess of 3 or 4 miles average length. Only one-man operation in congested streets and within a route length of 2 miles offers the opportunity for anything like a 5-cent fare.

The statements of the average jitney operator are poor guides to the correct cost estimate of a genuine motor-bus service. The jitneur works many more hours per day for himself than he would work for others, in running the car and in taking care of it. He has a direct incentive to collect all the fares and to waste no materials. He is just as liable as not to store his bus in the open. As for a standard of cleanliness, heating and maintenance, it does not exist and therefore costs nothing to get. The statements of builders are necessarily more general. It is right for them to expect a certain number of miles per gallon of gasoline and lubricant and to anticipate a certain maintenance cost and depreciation per mile on the assumption that the operator will be careful and that he is equipped with proper facilities. It is not right for the prospective purchaser to accept these estimates unless he knows he can fulfil the builders' expectations in those two respects.

Daily mileage is an important element in determining costs. There is a wide difference between the cross country vehicle that will make a practically non-stop run over a perfect highway with a good load between its terminals and the vehicle that will be used in any of the many varieties of city service. It makes a difference whether one runs 200 or 100 miles per day. The bus may be perfectly capable of doing 200 miles, but will there be any necessity for it in the given situation? As previously indicated, a number of uses for the motor-bus lie in the operation of extensions or crosstown services where traffic is thin and it is cheaper to have long lie-overs than to keep the vehicle shuttling back and forth. As a matter of fact, the operating cost of a modern safety one-man car is little more than half as much as the operating cost of a motor-bus of equal capacity. When we come to larger units, such as two-car and three-car surface trains, the disparity is just as great, aside from the fact that the same capacity in buses of single-deck type, in any case, would not be available in the same area. The superiority of the best motor-bus to the best street-car does not lie in any saving in operating or running costs. It lies in the ability to meet situations, some of which already have been described, that no track-bound vehicle of any type could solve. We cannot expect the bus to replace the car on a large scale except where the electric railway deliberately commits suicide. We can expect it to do what it already has done in Great Britain, to put a stop to all trackage development except extensions that will have heavy travel from the very first day that such routes are completely opened for the regular transportation of passengers.

The great sums that have been put into electric railways are not to be wiped out forthwith, although they are to be cut by the lopping off of weaker lines and small systems. But the future does belong almost entirely to the motor-bus because it makes possible the investment of capital in direct proportion to the business available instead of demanding almost as much investment for 50,000 as for 500,000 car-miles per annum. It is not necessary to assume the complete supersession of the electric city-railway as a necessity for large motor-bus development. The appetite of the people for transportation is far from satiated. What we should strive for is to secure constructive coordination rather than destructive competition, realizing that mass transportation is inherently a monopoly and should be under one direction whether the vehicles are propelled on a track or on tires, by electricity or by internal combustion. Only in that way will each form of transportation find its true economic place.

INTERNAL-COMBUSTION ENGINE FUELS

(*Concluded from page 192*)

prime requisite, in the case of which the relative merits of wet and dry mixtures are still debatable.

Professor Norman:—In that connection I would like to have the power of the tractor determined after it has been plowing several months. With a wet mixture including raw fuel entering the tractor-engine cylinders on starting, it passes the pistons, dilutes the crankcase oil and becomes mixed with some of the dust of the field in the cylinders. At the end of a season's plowing, on account of the leakage and friction, the condition is worse in point of power than it would be if the dry mixture had been used all the time.

Recent Aircraft Engine Developments

By C. FAYETTE TAYLOR[1]

DAYTON SECTION PAPER *Illustrated with* PHOTOGRAPHS

AFTER indicating the line of development since November, 1918, toward making the internal-combustion engine better adapted to aircraft service, the successful application of the supercharger to improve engine performance at great altitude is described and the over-dimensioned and over-compressed engine also is discussed as a means toward that end.

The use of anti-knock compounds to permit the use of high compression-ratios at small altitudes without knocking is commented upon and engine size is considered for both airplane and dirigible service. Further review includes air-cooling experiments in reference to the air-cooled radial engine, refinement of aviation-engine details, and improvements in aircraft powerplant parts and fuel-supply systems. For commercial aviation, powerplant reliability and low cost are stated as essentials. Illustrations are presented of the supercharger and of the engines and sylphon fuel-pump mentioned.

THE purpose of this paper is to outline briefly the most important advances in aircraft engines that have taken place since the armistice was signed on Nov. 11, 1918. These developments have been along the lines of improving engine performance at altitude, increasing power and efficiency through use of high compression and "doped" fuel, development of large engine units, experimentation in air-cooling, and refinement of detail, with a view to making the internal-combustion engine better adapted to aircraft service.

Perhaps the most notable of these developments is the successful application of the supercharger to improve engine performance at great altitudes. The desirability of supercharging was realized late in the war and several experimental superchargers were built and tested, but it was not until about six months after the armistice that the first successful flight while using a supercharger was made in this country. The supercharger used was designed by Dr. S. A. Moss of the General Electric Company, and was installed and flown at McCook Field by the engineering division of the Army Air Service. Fig. 1 is a photograph of the present type of General Electric supercharger mounted on a 12-cylinder Liberty engine. This supercharger is a development of the one that was first flown in the spring of 1919 and has been in successful use since that time. It is of the centrifugal compressor type, driven by a single-stage exhaust-driven turbine. The single rotating unit consists of a forged-steel compressor-rotor that is located in an aluminum housing at the front of the engine and on the same shaft with the turbine, which is immediately behind the engine. The compressor outlet discharges into the intercooler and thence to the carbureters. The intercooler is a new development and consists of a bank of exposed tubes to reduce the temperature of the air after it has passed through the blower and become heated by compression and friction. The speed of the turbine blower-unit, and hence the supercharging pressure, are controlled by the exhaust gates or bypass valves at the rear of the exhaust-manifolds, which govern the amount of exhaust gases going to the turbine. The normal speed of the rotating element is 20,000 r.p.m. The supercharger unit, as shown in Fig. 1, can be said to be a successful development in itself. However, the problems of fuel supply to the carbureters and of proper carburetion under supercharging conditions are not solved in a satisfactory manner, and much work remains to be done along this line. The cooling of the supercharged engine and the necessary variable-pitch propeller are special problems that already have been worked out in a fairly satisfactory manner.

THE OVER-DIMENSIONED AND OVER-COMPRESSED ENGINE

Another method of improving engine performance at altitude that has received much attention since the armistice is the over-dimensioned and over-compressed engine that has been developed from the normal type by increasing the cylinder bore and compression-ratio without increasing the size of the crankshaft, crankcase, connecting-rods or other important parts. At small altitudes, the oversize engine, as it is called, is held down to the maximum power output of the original normal engine by throttling but, above a certain height determined by the design, it can be run wide-open and advantage taken of the increased performance because of the larger displacement and increased compression-ratio. Due to the decreased air-density, the oversize engine is subjected to no higher cylinder pressures when run wide-open at or above its design altitude than the normal engine is when run wide-open at sea level. A remarkable feature of the over-compressed engine is the great fuel economy made possible by the high compression. Even when throttled to the maximum allowable power output at sea level, brake thermal efficiencies of over 28 per cent are obtained readily and it is probable that slightly higher efficiencies are obtained under favorable circumstances at the smallest altitude at which the engine can be run wide-open. Notable examples of over-dimensioned and over-compressed engines are the B.M.W. engine which was put into service by the Germans just before the armistice, and the Packard 12-cylinder engine, shown in Fig. 2, which is a joint development of the Packard Motor Car Co. and the engineering division of the Air Service. The Liberty engine also has been successfully modified to incorporate the over-compression feature and thus improve its performance at great altitude.

ANTI-KNOCK COMPOUNDS

Coupled closely with the development of the over-compressed engine is the adoption of special anti-knock compounds to be mixed with gasoline to allow the use of high compression-ratios at small altitudes without knocking or detonation. The work done by Thomas Midgley, Jr., of the General Motors Research Corporation, has been applied to aviation engines with distinct success. This is particularly useful in military work where the maximum possible power output of a given engine may be demanded at small altitudes, for special types of service. By using comparatively small quantities of these anti-knock com-

[1]Jun. S.A.E.—Engineer in charge of powerplant laboratory, engineering division, Air Service, McCook Field, Dayton, Ohio.

pounds, it has been possible to raise the compression-ratio of the Liberty engine sufficiently to increase the sea-level power-output 12 per cent without increasing the amount of fuel consumed. By sacrificing only a part of this gain in power and still using the anti-knock compound, the increased compression-ratio allows extremely lean fuel-mixtures to be burned with remarkable results in respect to fuel economy. Under such conditions the fuel consumption of the Liberty engine can be brought down to 0.44 lb. per b. hp-hr. in actual flight, or a brake thermal efficiency of nearly 30 per cent, which is considerably better than that of the average Diesel engine.

A notable instance of the possibility of obtaining high power-output by raising the compression-ratio and using an anti-knock compound is the case of a 5 x 7-in. cylinder used by the engineering division of the Air Service for test work. This cylinder repeatedly has given over 42

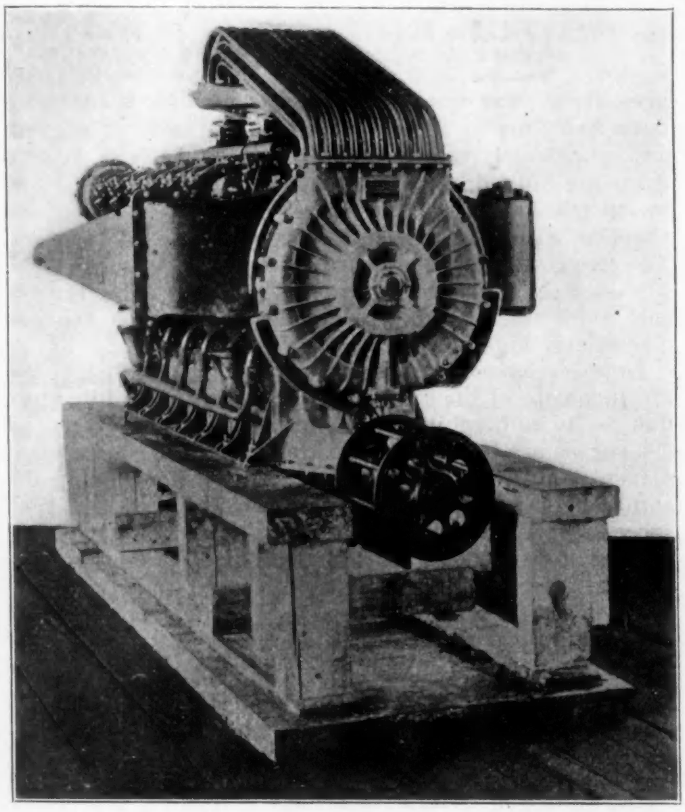


FIG. 1—THE MOSS SUPERCHARGER MOUNTED ON A 12-CYLINDER LIBERTY ENGINE

b. hp. at 1700 r.p.m., which corresponds to a brake mean effective pressure of 142 lb. per sq. in. and an indicated mean effective pressure of 177 lb. per sq. in. If the Ford engine could be made to give the same power-output in proportion to its displacement, 54 hp. would be developed instead of the normal output of 18 hp. A significant phase of the use of anti-knock compounds and high compression-ratios is that the maximum pressures that occur in the cylinder, and hence the maximum stresses in the engine, are not increased greatly. A considerable amount of detonation is present in aviation engines of normal compression-ratio using standard aviation fuel and, when this detonation is eliminated by an anti-knock compound, the compression-ratio can be increased considerably without reaching cylinder pressures as high as those of detonation under the normal conditions. By using a small percentage of such a compound in the fuel with engines of normal compression-ratio, it is expected that the life

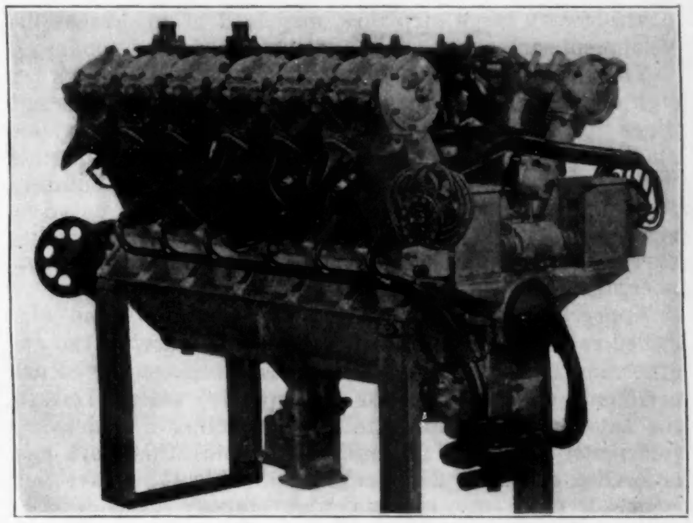


FIG. 2—A 12-CYLINDER ENGINE THAT WAS DEVELOPED JOINTLY BY THE PACKARD MOTOR CAR CO. AND THE ENGINEERING DIVISION OF THE AIR SERVICE

of the engine and its reliability can be increased considerably.

AIRCRAFT-ENGINE SIZE AND COOLING

In regard to engine size, the advent of aviation engines of over 500 hp. has been a distinct development since the armistice. The only successful engine of over 500 hp. to be flown before the armistice was the Italian 12-cylinder F.I.A.T., that was rated at 650 hp. This is a very heavy engine for its power, and just how successful it has been is open to question. Since the armistice there have been designed and built in England four types of engine of 500 hp. or over, one of which, the Napier Cub, has been reported recently to have developed over 1000 b. hp. on test. Approximately 12 engines of 500 hp. or over have been designed in France, but just how many of them have been actually built and tested is not known. So far as can be learned, none of the large British or French engines has yet passed the experimental stage. This country has produced the 500-hp. Packard engine shown in Fig. 3 and the engineering division of the Air Service the 700-hp. Model-W engine illustrated in Fig. 4, both of which bid fair to be successful types. Plans are being laid in this Country for even larger engines and the limit in the size and number of cylinders has not yet been reached. It is believed that the large engines, making

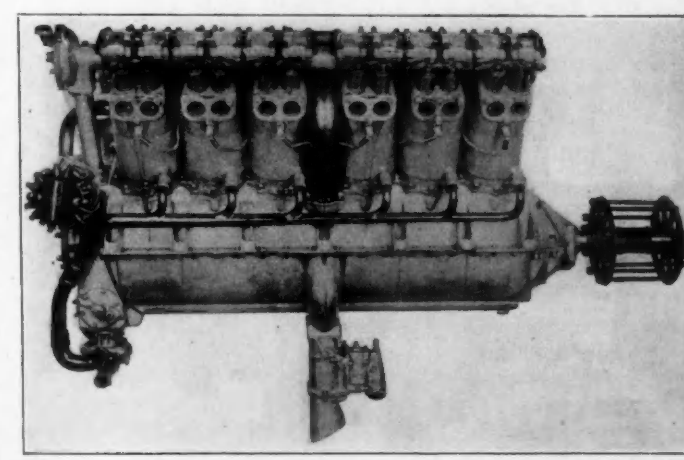


FIG. 3—THE 550-HP. ENGINE PRODUCED BY THE PACKARD MOTOR CAR CO.

possible very large airplanes, may lead to unforeseen developments in commercial as well as military aeronautics.

The situation in this Country in regard to engines for lighter-than-air service has improved to some extent since the armistice. At that time there was only one small American engine designed especially for dirigible use. At present at least two American firms are building 350-hp. engines that incorporate all of the most uptodate requirements of this service. This development is being carried on under the direction of the Bureau of Engineering of the Navy Department.

Appreciating the important advantages of the air-cooled radial engine for certain classes of service, the engineering division of the Air Service has conducted experiments on air-cooling on an extensive scale. Due to the extraordinary difficulties in air-cooling cylinders of sufficiently large size for military engines, this work has proceeded slowly and no engines of this type have yet emerged from the experimental stage. Considerable progress has been made, however, and it can be predicted confidently that a successful air-cooled engine of over 300 hp. will be forthcoming within the present year. In connection with the subject of air-cooling considerable credit is due the Lawrence Aero Engine Corporation for having developed a small air-cooled aviation engine the performance of which equals that of the average water-cooled aviation engine in proportion to its displacement.

Aircraft Powerplant Refinement

In addition to the specific developments already described, there has been remarkable refinement of detail in aviation engines. From the viewpoints of maintenance, installation, and accessibility of those parts requiring frequent attention in particular, much progress has been made. Figs. 2 and 3 show in part how this has been accomplished. The absence of accessories on the anti-propeller end of the engine, which usually abuts a fire-wall in an airplane installation, is particularly noticeable. The carbureters are located below the crankcase both for accessibility and to allow the use of gravity fuel-feed. The water pump, oil-screen, ignition apparatus and spark-plugs, where possible, are all located so as to be accessible from the sides. The importance of such details in aviation work cannot be overestimated, because so much depends upon keeping the engine accessories in good condition.

Parts of the aircraft powerplant outside of the engine have been undergoing steady development. This is especially the case with the cooling system. Relieved from the pressure of war work, the various research laboratories have had time to determine carefully the most efficient and practical types of radiator core. The best modern cores are built up of thin copper tubes approximately 1/4 in. in diameter; and these are expanded to hexagonal shape at either end, where they are soldered together. The length of the tubes varies from 4 to 9 in., depending upon the air velocity through the core. This type of core lends itself readily to quantity production and has a relatively high efficiency.

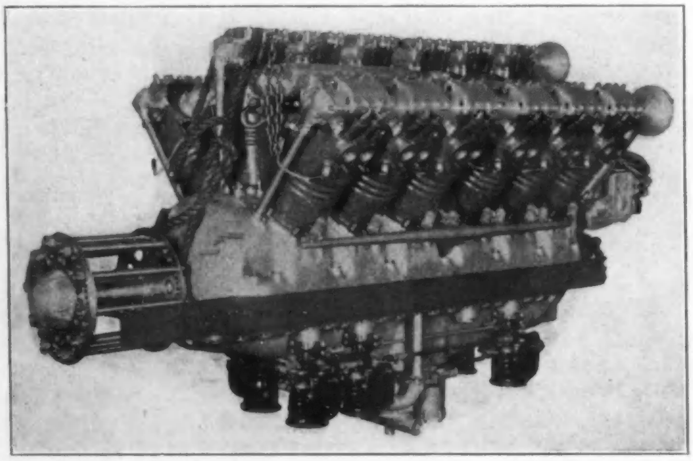


Fig. 4—The 700-Hp. Model W Engine Developed by the Air Service

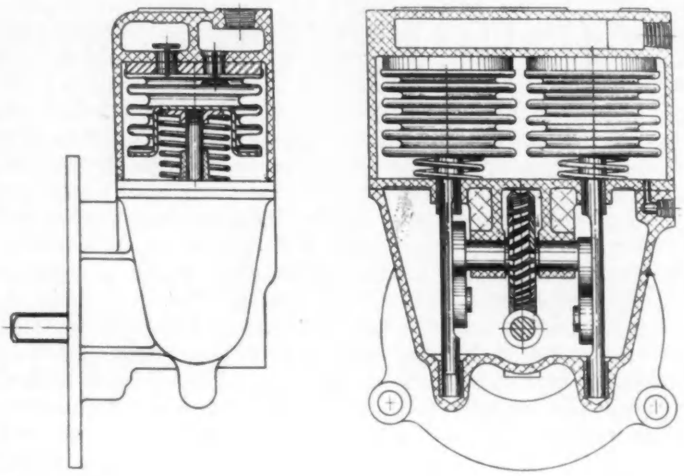


Fig. 5—The Sylphon Pump for the Fuel-Supply System of an Airplane That Was Designed by the Air Service

New developments in the fuel-supply system include the abandonment of the air-pressure method for military use, due to its vulnerability. Instead, fuel-pumps driven by the engine are becoming almost universal, although wind-driven pumps are still popular. The sylphon pump designed by the Air Service and shown in Fig. 5 is a very successful engine-driven pump of which the operating member consists of a pair of cylindrical metal bellows operated by cams, with a spring return to limit the maximum pressure without the use of relief valves. For military service an auxiliary system is invariably supplied, which is either gravity or hand-operated. Commercial powerplants usually employ the air-pressure system because of its simplicity and reliability.

One thing that does not appear to have been developed in this Country is an engine entirely suitable for commercial aviation. Here powerplant reliability becomes a very important factor, since the safety of the passengers or the goods carried depends upon the continuous operation of the engine. This aspect of the situation has been obscured somewhat in military aeronautics, where many other factors are thought to be of nearly equal importance. It is believed that the greatest single step toward successful commercial aviation would be the development of a powerplant as reliable as that of the marine steam-engine. The problem of reliability is as much one of the smaller parts of the powerplant, such as the fuel-supply and the ignition systems and spark-plugs, as it is of the engine itself, and in making these parts more dependable lies an important field for future development.

Another extremely important requirement of the commercial engine is low cost. Here, again, the military designs, in which cost is a minor consideration, have exerted a retarding influence. Present-day airplane engines are enormously expensive in both initial cost and maintenance and until this phase of the situation shall have been overcome the development of the commercial airplane engine will be very slow.

Drop-Forging Practice

By J. H. Nelson[1] ANNUAL MEETING PAPER

THE author discusses drop-forging practice from the standpoint of the materials used, and strongly advocates a more rigid inspection and testing of raw products to determine their fitness for use in making automatic forgings.

Seven specific possibilities of actual difference between drop-forgings that are apparently identical are stated, the requirements of the inspection of raw stock are commented upon, and the heat-treatment and testing of finished forgings are considered at some length.

Tabular data of the chemical analyses and physical properties of 107 different heats of carbon-steel used recently are presented and show a variation in drawing temperatures of 140 deg. fahr. in steels of practically the same chemical composition to meet the same physical-property specification, based on more than 1000 tests on this grade of steel taken from production stock. The concluding summary has five specific divisions.

SOME very rapid and stupendous developments have occurred in a large number of industries within the past decade. Chief among these is the automotive industry, which has forged forward from a comparatively inconspicuous beginning to become one of the largest and most highly specialized industries of today. One of the principal reasons for this rapid development is the willingness and eagerness with which those in responsible charge seized upon and completely assimilated new ideas and methods that make for better and more rapid production. Many industries have contributed toward this development either directly or indirectly. It is impossible to measure with any degree of accuracy the exact value of each of their contributions. The drop-forging industry, which itself is comparatively young, has contributed in a large measure to this phenomenal advance by successfully forging from steels of various compositions some of the most vital parts that enter into the construction of automotive vehicles. In the early history of the automotive industry, when quantity requirements were small, the cost of drop-forgings was prohibitive to a large extent. The result was that the manufacturer was compelled to resort to castings or hand-forgings to supply his needs. As his requirements increased and designs became more stabilized, he was able to purchase drop-forgings of far superior quality to compete in price with castings and hand-forgings.

Drop-forgings for automotive construction are made today in large quantities from a great variety of steels, both plain-carbon and alloy, the particular grade of steel used being dependent upon the part to be forged and the duty required of the part. With the increase in the number of forge-shops that has occurred within the last few years, it is no longer a problem to have a forging made, but rather to secure the necessary quality in the forging when completed; and this matter of satisfactory quality is not something that is apparent on the surface of the forging. Two forgings may be identical in appearance, size, shape, amount of finish and even forged from the same grade of material; yet, from a quality standpoint, they may be decidedly different. This difference may be due to any one or to a combination of the following factors

(1) Method of forging
(2) Method of heating for forging
(3) Inspection and supervision of forging
(4) Inspection of raw stock
(5) Segregation of raw stock
(6) Heat-treatment of the finished forging
(7) Testing of the finished product

It is not the intention to discuss the effects of all of these factors on a finished forging, but rather to confine the discussion to the last four, these having to do with the materials entering into the forging and with its subsequent treatment.

INSPECTION OF RAW STOCK

Inspection of raw stock should consist of (*a*) surface inspection to determine the fitness of the material for use in forgings, such as an examination for size, seams, scale, burns and the like, and (*b*) chemical analysis to determine the fitness for use in the various parts, to determine the segregation of the elements in the bars and to determine mixed heats.

Mixed heats are of two kinds, those that are deliberately mixed at the mill and those that are accidentally mixed at the mill. Under deliberately mixed heats, we find steels of the same grade but from different melts that are rolled into bars and furnished to a customer under the same heat number. Such heats are made up from ingots that have the same or nearly the same chemical composition as to the hardening or alloying constituents. Heats of this character are an endless source of trouble to forge-shops that endeavor to keep melts of steel of the same grade segregated. Unintentionally mixed heats are due to a few bars of a different grade of steel becoming misplaced. While this is a source of annoyance, it is readily detected chemically and the bars are then rejected.

SEGREGATION OF RAW STOCK

Segregation of raw stock of the same grade by melts is absolutely essential if quality forgings are to be produced. Many shops and plants fail to recognize this fact and segregate their stock by size and grade only. It not only is necessary to segregate the stock in the yard, but it is equally necessary to segregate the forgings made from this stock until they have been completely heat-treated and are ready to ship to the customer.

HEAT-TREATMENT OF FINISHED FORGINGS

The necessity for segregation of raw materials as well as segregation throughout the entire process of fabrication can best be demonstrated by our experience on production work. Time and space will not permit of the discussion of the different grades of steels used. The tendency found in the simple carbon-steel summarized in Table 1 holds for all steels, including the more complex alloy-steels. Table 1 gives chemical analyses and physical tests on production work for 107 different melts of a plain carbon-steel purchased under the specification given at the head of the table.

These steels were purchased from a number of different mills and are fairly representative of material selected for our use.

[1] M.S.A.E.—Chief metallurgist, Wyman-Gordon Co., Worcester, Mass.

TABLE 1—CHEMICAL ANALYSES AND PHYSICAL TESTS MADE ON A 0.40 TO 0.50-PER CENT CARBON STEEL

No.	C 0.400 to 0.500	Mn 0.600 to 0.800	P 0.045 max.	S 0.050 max.	Yield-Point, lb. per sq. in.	Tensile-Strength, lb. per sq. in.	Elongation in 2 In., per cent	Reduction of Area, per cent	Brinell Hardness No.
Group A—Drawing Temperature, 980 Deg. Fahr.									
1	0.440	0.730	0.010	0.033	77,150	117,600	19.8	50.5	245
2	0.390	0.630	0.015	0.038	72,875	111,550	20.0	52.1	237
3	0.400	0.620	0.016	0.050	72,700	109,300	21.7	53.0	230
4	0.420	0.680	0.015	0.051	73,600	108,400	18.0	50.3	242
5	0.500	0.580	0.008	0.043	72,000	108,475	19.8	50.7	236
6	0.440	0.670	0.010	0.043	76,800	112,000	21.3	54.9	241
Group B—Drawing Temperature, 1,000 Deg. Fahr.									
7	0.480	0.800	0.015	0.048	76,350	115,600	21.9	53.0	233
8	0.470	0.650	0.009	0.044	76,950	115,425	20.4	50.6	233
9	0.420	0.680	0.019	0.044	76,300	113,200	20.3	53.3	241
10	0.410	0.660	0.015	0.040	78,350	115,950	20.0	52.7	237
11	0.390	0.690	0.0 9	0.042	74,700	110,700	21.6	52.9	238
12	0.420	0.740	0.014	0.038	77,775	115,500	21.9	54.1	236
13	0.430	0.700	0.015	0.039	81,350	122,800	19.6	53.0	241
14	0.400	0.620	0.019	0.035	78,300	117,100	20.3	51.2	238
15	0.480	0.680	0.016	0.034	80,200	118,325	19.8	52.4	238
16	0.410	0.780	0.027	0.042	75,150	112,625	22.2	55.4	241
Group C—Drawing Temperature, 1,020 Deg. Fahr.									
17	0.460	0.740	0.014	0.034	74,575	110,400	21.2	55.8	234
18	0.430	0.740	0.018	0.032	75,625	114,250	21.5	53.3	236
19	0.470	0.630	0.014	0.046	77,200	116,600	22.2	52.5	230
20	0.470	0.630	0.017	0.053	75,450	115,450	20.4	51.7	238
21	0.480	0.730	0.020	0.043	76,250	114,900	21.5	52.6	238
22	0.540	0.630	0.020	0.039	82,400	122,800	21.1	51.5	238
23	0.470	0.740	0.018	0.058	79,200	118,000	22.4	53.8	240
24	0.430	0.590	0.016	0.031	76,400	113,900	22.8	56.0	241
25	0.510	0.750	0.028	0.034	78,450	117,250	21.7	54.5	239
Group D—Drawing Temperature, 1,040 Deg. Fahr.									
26	0.500	0.650	0.022	0.048	78,800	117,370	19.5	50.6	239
27	0.490	0.750	0.015	0.040	77,420	114,200	20.7	51.8	236
28	0.480	0.700	0.024	0.042	78,000	119,400	20.9	52.3	239
29	0.520	0.700	0.018	0.046	76,500	115,600	20.1	53.4	241
30	0.500	0.560	0.022	0.046	75,350	114,175	19.8	51.2	238
31	0.500	0.690	0.018	0.042	79,500	116,350	21.2	53.7	241
32	0.500	0.690	0.016	0.041	76,150	116,350	20.0	50.8	238
33	0.480	0.820	0.019	0.053	79,780	118,500	20.3	52.3	241
34	0.470	0.720	0.015	0.042	75,100	113,900	20.3	50.2	235
35	0.420	0.680	0.019	0.044	76,300	113,200	20.3	53.3	241
36	0.480	0.640	0.022	0.012	77,425	116,125	22.8	54.3	238
37	0.440	0.660	0.022	0.039	79,960	118,120	20.8	53.0	241
38	0.520	0.830	0.031	0.041	77,400	112,900	21.0	55.2	243
39	0.510	0.710	0.042	0.045	78,300	116,600	23.4	55.8	240
40	0.480	0.650	0.024	0.046	79,870	118,200	20.3	52.3	236
41	0.480	0.820	0.025	0.056	76,275	114,800	21.0	52.9	239
42	0.490	0.660	0.026	0.052	78,850	116,600	22.0	52.5	237
43	0.460	0.780	0.009	0.053	75,450	113,125	23.2	56.5	233
44	0.470	0.800	0.014	0.045	77,400	115,500	22.6	55.0	233
45	0.400	0.880	0.010	0.048	76,250	112,850	21.8	55.6	237
46	0.450	0.700	0.036	0.043	74,900	114,000	22.3	53.4	235
47	0.400	0.830	0.026	0.046	79,000	117,400	22.8	55.2	241
48	0.460	0.750	0.017	0.043	78,650	116,750	23.0	56.5	234
Group E—Drawing Temperature, 1,060 Deg. Fahr.									
49	0.500	0.700	0.021	0.043	79,850	118,100	20.7	51.0	235
50	0.450	0.680	0.018	0.054	78,150	116,000	20.3	52.1	241
51	0.480	0.630	0.026	0.042	77,925	116,900	21.6	53.9	241
52	0.470	0.700	0.028	0.040	76,325	113,125	21.3	55.6	233
53	0.480	0.820	0.028	0.053	79,550	117,400	20.4	54.9	240
54	0.470	0.780	0.030	0.042	76,850	115,750	22.1	54.0	237

TABLE 1—CHEMICAL ANALYSES AND PHYSICAL TESTS MADE ON A 0.40 TO 0.50-PER CENT CARBON STEEL (CONCLUDED)

No.	C 0.400 to 0.500	Mn 0.600 to 0.800	P 0.045 max.	S 0.050 max.	Yield-Point, lb. per sq. in.	Tensile-Strength, lb. per sq. in.	Elongation in 2 In., per cent	Reduction of Area, per cent	Brinell Hardness No.
Group E—Drawing Temperature, 1,060 Deg. Fahr. (Concluded)									
55	0.400	0.890	0.012	0.048	76,250	112,850	21.8	55.6	237
56	0.490	0.610	0.013	0.031	73,500	1[illegible]7,700	22.9	57.5	233
57	0.470	0.700	0.033	0.031	81,200	119,310	20.8	53.0	243
58	0.4[illegible]0	0.780	0.035	0.051	76,870	115,600	22.4	54.5	239
59	0.430	0.650	0.022	0.036	75,950	113,000	23.3	55.5	237
60	0.460	0.690	0.032	0.051	76,600	113,950	22.0	53.6	240
Group F—Drawing Temperature, 1,080 Deg. Fahr.									
61	0.460	0.810	0.017	0.043	79,270	118,500	21.0	54.0	238
62	0.520	0.580	0.026	0.049	76,250	115,900	21.2	56.7	237
63	0.480	0.640	0.022	0.054	77,370	117,100	20.8	52.5	239
64	0.480	0.730	0.034	0.046	80,500	119,900	20.3	50.0	238
65	0.480	0.700	0.033	0.056	79,200	116,500	20.0	53.6	233
66	0.450	0.680	0.018	0.054	77,750	117,150	19.7	51.1	242
67	0.490	0.750	0.026	0.055	77,500	115,900	22.3	55.4	235
68	0.480	0.650	0.025	0.042	79,600	117,900	20.9	52.1	238
69	0.450	0.730	0.027	0.043	82,187	121,000	19.7	51.7	241
70	0.440	0.760	0.025	0.049	79,600	119,[illegible]00	19.9	52.2	242
71	0.450	0.610	0.023	0.040	78,750	114,700	20.7	54.2	245
72	0.460	0.740	0.039	0.040	79,270	115,500	20.5	54.1	242
73	0.480	0.630	0.040	0.043	77,000	113,950	21.1	52.7	247
74	0.460	0.830	0.034	0.047	76,500	113,000	21.4	54.0	246
75	0.490	0.770	0.028	0.041	79,450	118,500	22.4	54.2	237
76	0.430	0.790	0.021	0.043	81,400	120,900	21.6	52.9	241
77	0.470	0.760	0.022	0.046	82,000	121,700	19.5	51.9	242
Group G—Drawing Temperature, 1,100 Deg. Fahr.									
78	0.480	0.730	0.014	0.039	78,250	117,625	21.8	55.9	237
79	0.460	0.730	0.015	0.036	78,350	115,300	21.6	56.0	244
80	0.460	0.690	0.041	0.048	75,100	113,900	20.6	52.2	243
81	0.440	0.760	0.023	0.049	77,100	112,500	21.1	56.2	243
82	0.420	0.790	0.034	0.046	75,200	112,160	22.1	54.5	241
83	0.500	0.660	0.030	0.037	76,970	116,100	20.3	52.8	241
84	0.480	0.690	0.039	0.051	76,600	112,950	21.5	57.0	246
85	0.430	0.920	0.038	0.038	76,200	113,900	24.0	57.3	238
86	0.430	0.810	0.027	0.032	77,900	115,000	23.5	57.2	241
87	0.400	0.850	0.035	0.046	78,600	117,120	22.9	54.6	242
88	0.460	0.610	0.034	0.039	75,650	113,600	23.6	57.6	238
Group H—Drawing Temperature, 1,120 Deg. Fahr.									
89	0.460	0.740	0.039	0.040	79,300	115,500	20.5	54.1	242
90	0.500	0.780	0.033	0.041	82,250	120,650	19.9	55.0	248
91	0.440	0.820	0.028	0.044	78,950	110,500	22.5	59.7	243
92	0.460	0.690	0.032	0.043	81,000	118,750	21.1	53.5	247
93	0.450	0.880	0.036	0.034	79,450	115,950	21.7	57.5	243
94	0.480	0.740	0.033	0.043	77,750	115,200	22.0	54.8	241
95	0.400	0.700	0.033	0.043	74,700	110,000	22.4	57.1	241
96	0.500	0.800	0.035	0.047	82,150	119,300	20.8	54.3	246
97	0.480	0.680	0.025	0.037	77,750	115,850	21.7	56.6	239
98	0.420	0.850	0.038	0.042	77,750	113,550	22.3	59.7	243
99	0.440	0.860	0.031	0.037	78,500	117,000	21.8	57.2	247
100	0.440	0.950	0.025	0.055	75,500	111,100	21.2	57.1	240
101	0.480	0.710	0.033	0.055	80,200	117,900	21.3	54.4	247
102	0.420	0.870	0.035	0.048	83,000	120,625	21.6	54.1	243
103	0.460	0.790	0.036	0.042	81,000	118,425	21.8	54.2	240
104	0.460	0.700	0.035	0.043	79,000	118,000	21.3	52.5	243
105	0.450	0.690	0.029	0.048	75,250	111,500	23.1	56.0	239
106	0.440	0.630	0.028	0.046	76,250	113,650	23.6	57.8	237
107	0.490	0.750	0.026	0.051	78,200	114,800	21.4	56.4	243

The physical properties given in Table 1 are an average of ten tests selected at random for each melt, the tensile test in every case having been made on a prolongation of a crankshaft that was forged to a diameter equal to the maximum section of the shaft. In our practice this coupon remains attached to the crankshaft throughout the various operations and is used as a check on the heat-treatment operations. One or more such tests are provided for each furnace charge, the number depending upon the number of crankshafts in each charge. The diameters used vary from 2¼ to 2¾ in., according to the particular job that is being forged.

The location of test-specimens was in every case at a point halfway between the outside and the center of the coupon. The axis of the test-specimen was always taken parallel to the axis of the coupon from which it was cut. The test-specimen used conforms to the Society's standard dimensions, 0.505 in. diameter and 2-in. gage-length. The tensile tests were all made on a 100,000-lb. capacity automatic and autographic tensile-testing machine, using the 50,000-lb. counterpoise on the beam. spherical-seated grips are used in making all tensile tests. The Brinell hardness number recorded was determined on the crankshaft after first grinding and preparing the surface it does not necessarily indicate the hardness of the test-piece itself.

A study of the results given in Table 1 would lead to the conclusion that the chemical composition of the steel in question is not a complete criterion of the heat-treatment to be specified to meet the requirements of a definite specification. We see that the steels reported require a drawing temperature varying from 980 to 1120 deg. fahr. to bring them within the limits specified. The uniformity of the results obtained in the various groups is exceedingly striking, as is also the uniformity between the various groups.

This latter uniformity is more evident in Table 2 where the averages of the various groups given in Table 1 are summarized. This summary brings out more clearly that the variation in the drawing temperatures necessary to bring these various heats of steel to the common specification cannot be ascribed wholly to the difference in the chemical composition of the heats. The variation in the average carbon and manganese-content of these steels will not account for the large variation in drawing temperatures.

It does not require much play of the imagination to visualize the condition of a charge of steel made up from each of these groups and treated as a single melt. Such, however, is the condition when stock is kept only by size and grade. This condition can also exist in a heat of steel that is intentionally mixed at the mill. The chemistry of the steel, as has been shown, is not a sufficient criterion to allow any person to prescribe heat-treatments with any degree of accuracy. The only safe way to determine this is by actual experimentation for each melt of steel used.

TABLE 2—AVERAGE OF VALUES GIVEN IN TABLE 1

Group	Drawing Temperature, deg. fahr.	C 0.400 to 0.500	Mn 0.600 to 0.800	P 0.045 max.	S 0.050 max.	Yield-Point, lb. per sq. in.	Tensile-Strength, lb. per sq. in.	Elongation in 2 In., per cent	Reduction of Area, per cent	Brinell Hardness No.	Number of Tests Averaged
A	980	0.430	0.650	0.012	0.043	74,280	111,220	20.1	51.9	238	60
B	1,000	0.430	0.690	0.016	0.041	77,540	115,900	20.8	52.8	238	110
C	1,020	0.470	0.690	0.018	0.041	77,300	115,950	21.6	53.6	237	90
D	1,040	0.470	0.730	0.021	0.044	77,500	115,750	21.3	53.3	238	230
E	1,060	0.460	0.710	0.024	0.042	77,420	114,980	21.6	54.3	238	120
F	1,080	0.460	0.710	0.028	0.046	79,100	117,500	20.8	53.1	240	170
G	1,100	0.450	0.750	0.021	0.042	76,900	114,600	22.1	55.2	241	110
H	1,120	0.450	0.770	0.032	0.044	78,800	115,700	21.7	56.0	243	190

The crankshafts represented by these tests were all quenched in water from 1525 deg. fahr., and drawn back to the temperature specified. The furnaces used are automatically controlled, use oil for fuel and have a hearth dimension of 66 x 98 in. The temperatures were all measured by an iron-constantin thermocouple pyrometer system, which was checked constantly by a master pyrometer used exclusively for this purpose. The control mechanism, which is very positive in its action, is responsive to changes of 5 deg. in temperature between fire-off and fire-on. The charge of any furnace can be held for any length of time at any predetermined temperature, without danger of over-running as in hand-fired furnaces. This insures accuracy in heat-treating operations.

The values given in Table 1 have been grouped according to the drawing temperature necessary to meet the following specification

SPECIFICATION OF PHYSICAL PROPERTIES

Yield-Point, lb. per sq. in.	70,000
Tensile-Strength, lb. per sq. in	100,000
Minimum Elongation in 2 In., per cent	18
Minimum Reduction of Area, per cent	50
Brinell Hardness	228 to 248

Testing Finished Forgings

The test applied to finished forgings is a series of either tensile or Brinell-hardness tests, the latter being more extensively used. For quality forgings, both should be used. It is comparatively easy to treat any heat of steel to meet either of these two tests when used separately but, when both conditions are to be met at the same time, the task becomes somewhat more difficult and with some melts of steel it is impossible. When the Brinell-hardness test only is used to test forgings, nothing short of at least one Brinell test on each forging should be countenanced. If this is not done and the various melts of steel used are not segregated throughout the yard and shop, some poorly treated forgings are sure to be the result.

Summary

(1) Steels of the same grade and of the same chemical composition do not respond in the same way to heat-treatment

(2) To heat-treat with minimum loss, only steels from the same melt should be included in a furnace charge

(3) Stock subjected to heat-treatment should be carefully segregated into piles of the same melt; it should be kept segregated throughout the entire process of fabrication to produce satisfactory forgings of uniform quality

(4) Tensile and hardness tests should be required on all heat-treated forgings to check the thoroughness with which the various heat-treatment operations were performed

(5) At least one hardness test should be made on all heat-treated forgings to insure that all have responded to the heat-treatment operations in the same manner

COMMERCIAL-BODY SUPPLY AND SERVICE

(*Concluded from page* 186)

sectional bodies; so that, while much might be done profitably in the standardization of chassis for commercial cars, the situation at present is such as to give the user some latitude in the choice of chassis and at the same time secure the benefits of the standardized body. To only a slightly less extent this condition also holds for 1-ton trucks. All this has been accomplished, not because of recognized standards, but in spite of the absence of such standards.

Trucks of greater capacity have not been produced in sufficient quantity in any one make or model to give the standardized heavy-duty truck-body a fair chance. While the advance already attained in the commercial and light-truck business serves to emphasize the pressing need for truck-body standardization, this standardization cannot be carried out successfully until the truck chassis has been standardized. It is doubtful whether any single step could be of more immediate advantage to the truck industry than standardizing chassis body-mounting dimensions, thus enabling body production to be put on a manufacturing basis. There is now a vast difference in all chassis dimensions that have to do with the fitting of the body, such as frame widths and lengths, rear-wheel dimensions, wheelbases, driver's seat and its location and all controls. Standardizing frame widths and rear-wheel dimensions would help the body-builder most, but the length of the frame back of the driver's seat and the distance from the driver's seat to the rear axle should be given attention at the same time, establishing, say, a range of three lengths for each body-capacity. If, in addition to a uniform practice in these dimensions, agreement could be effected on a standard difference between the height of the frame from the ground and the diameter of the rear wheel for each capacity of truck, the heavy-duty body-builder would be able to count on a sufficient volume of demand to justify marketing standardized bodies for these trucks, and the truck builder, the dealer and the user would enjoy all the advantages that now accrue only in the commercial car and light-truck field.

By such a process of standardization, not only the body-builders, but all suppliers of material to them could adopt standards that would reduce their costs greatly, and so through every process of the body industry effect remarkable savings. The delivery to the dealer of the mounted body could be made immediately from stocks of bodies, including a wide range of styles, carried by body-builders having branches, or distributors, throughout the country. There would be an enormous elimination of waste through the user getting his truck and body into profitable operation without any loss of time and continuing their use without expensive lay-ups for repairs; all on account of the superior service all along the line that can be made possible only by the standardization of such chassis dimensions as affect body mounting.

1922 SUMMER MEETING

WHITE SULPHUR SPRINGS, W. VA.

JUNE 20-24

AS this issue of THE JOURNAL goes to press, the Meetings Committee of the Society announces the selection of White Sulphur Springs, W. Va., as the location of the 1922 Summer Meeting. Rates, reservation blanks and a description of this unusually attractive resort will soon reach the members in *The Meetings Bulletin.*

Highway Transportation as It Affects the Automotive Engineer

By E. W. Templin[1]

Pennsylvania Section Paper

Illustrated with Photographs ahd Charts

STATING that the means and methods of transporting freight over the highways are governed by six factors, the author enumerates them as being the number of ton-miles of goods to be shipped, the shipping points and destinations, the kinds of highway available, the types of vehicle most suitable, the cost of operation per ton-mile and the rates that should be charged for the service. The purpose of the paper is not to answer these questions but to determine if present practice is headed in the right direction.

The conditions the highway must meet, in addition to the gross load of the vehicles, are the maximum tire load, the pressure per square inch exerted by the tire upon the pavement and the value of any impact blow upon the pavement. The impact blows of pneumatic tires are practically negligible, while solid tires build up the impact to many times the weight of the wheel load; this is proved by impact tests of tires which are described in some detail and illustrated.

The state of development of the pneumatic truck tire and average mileage obtained by its users are treated specifically, spring suspension and steering are discussed, a summary is presented in three divisions and an appendix, giving three specific results of tests made by the Bureau of Public Roads on the six-wheel truck the author describes, is included.

HIGHWAY transportation is being recognized as a way of augmenting other present means for transporting goods. It offers a large field when the possible magnitude of the ton-mileage that can be delivered over the highways is considered. The means and methods for transporting freight over the highways are governed by the following factors:

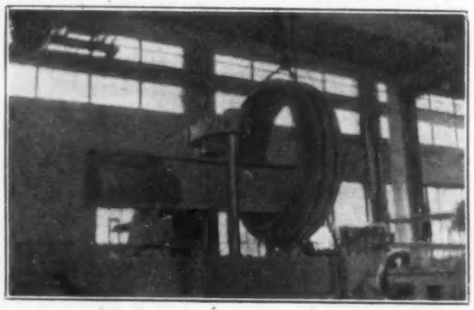


Fig. 1—Beam-Testing Machine Employed in Making Impact Tests of Solid and Pneumatic Tires

(1) Number of ton-miles of goods to be transported
(2) Shipping points and destinations
(3) Kind of highways available
(4) Types of vehicle most suitable
(5) Cost of operation per ton-mile
(6) Rates that should be charged for the service

The purpose of this paper is not to answer these questions but to determine if present practice is headed in the right direction. Quoting from *Good Roads*

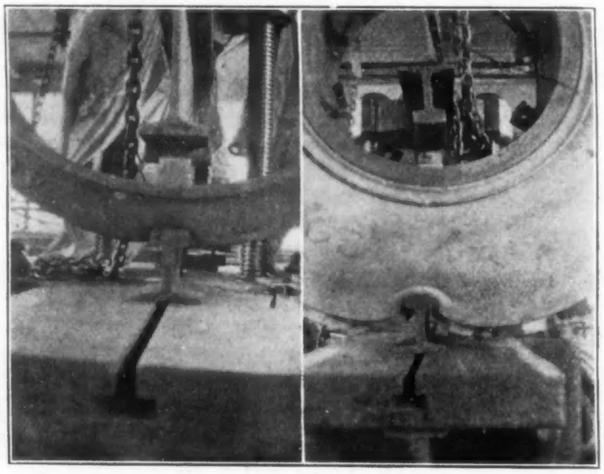


Fig. 2—Close-Up Views of a 6-In. Solid Tire at the Left and an 8-In. Pneumatic Tire at the Right Being Pressed Over a 70-Lb. Railroad Rail

> Almost every day brings a new example of the dependence upon motor trucks for the transportation of goods. Foodstuffs are hauled from the farms to markets, lumber is brought out of the forests, raw materials of one kind and another are carried to the factories and manufactured articles are distributed to wholesalers and retailers. Much of this business is of the short-haul variety, but a considerable portion is long-distance hauling. Regular routes of 500 to 600 miles no longer attract general attention. This development of truck hauling is due to the growing appreciation of the advantages of highway transportation. In view of the ever-increasing demand for long-distance truck-hauling it seems self-evident that there is a greater need than ever before for the betterment of the highways. If trucks are to render anything like the maximum service of which they are capable, at least passable roads must be provided for their operation.

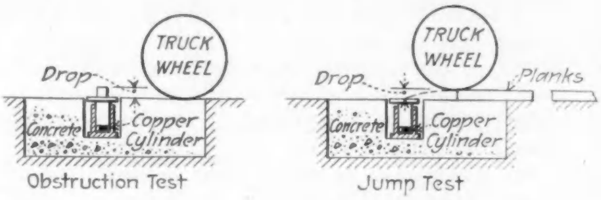
Quoting again the same source we find that, by the use of highway transportation, production can be increased, costs reduced and an increased revenue to the producer assured.

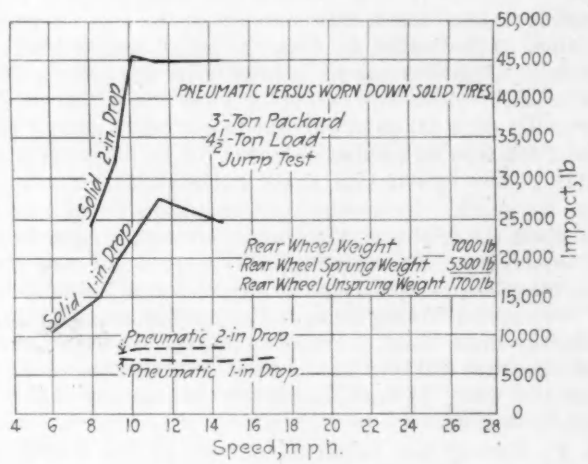
> It is possible to double farm production by saving what is now wasted. This makes possible a wider producing area and assures the prompt arrival of perishable goods at the door of the consumer when they are in the best condition and command the highest price.
>
> It is necessary that good roads be available 365 days of the year. This involves a system of snow removal. During the war snow removals under State and National direction were organized. This work could well be continued now, especially in keeping open that 20 per cent of roads on which 90 per cent of highway traffic is concentrated.
>
> The automotive industry recognizes the menace to the highways of excessively heavy trucks, and advocates that no vehicle weighing more than 28,000 lb. gross load shall be permitted the use of the public high-

[1] M.S.A.E.—Motor-truck engineer, development department, Goodyear Tire & Rubber Co., Akron, Ohio.

way as at present constructed. It believes also that the increasing use of pneumatic tires on trucks will reduce the damage. We are equally convinced that the highways of the future should be the servants of transportation, not its master. They should be prepared to accommodate a constantly increasing volume of haulage carried by trucks of whatever size that shall prove most swift, efficient and economical.

The conditions the highway must meet, in addition to the gross load of the vehicles, are the maximum tire load, the pressure per square inch exerted by the tire upon the pavement and, since there are irregularities in any kind of pavement, the value of any impact blow that the tire may exert upon the pavement. Pneumatic truck tires do not in any measure reduce the maximum load per tire, but they decrease the pressure per square inch upon the pavement. They present twice the area of contact on the pavement that solid tires of corresponding capacity present. More important, however, is the fact that the impact blows of pneumatic tires upon the pavement are





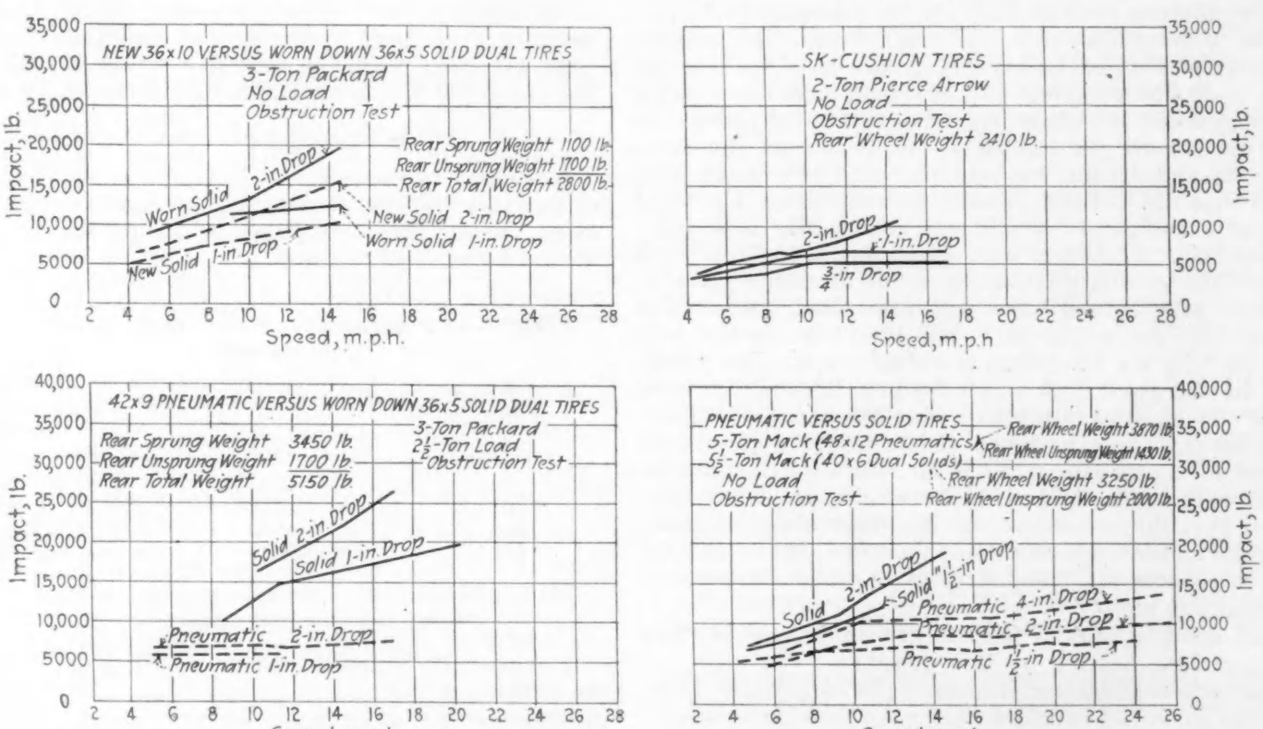


FIG. 3—RESULTS OF TESTS OF VARIOUS SIZES OF TIRES CONDUCTED BY THE BUREAU OF PUBLIC ROADS OF THE DEPARTMENT OF AGRICULTURE

practically negligible, while solid tires build up impact blows to many times the weight of the wheel load. The truth of this statement is evidenced by the following tests.

Impact Tests of Tires

A 6-in. solid tire was compared with an 8-in. pneumatic tire, since in practice they are used to carry corresponding loads. Each tire was placed in a beam testing machine, as indicated in Figs. 1 and 2, and a load was gradually applied so as to depress the tire over a 70-lb. railroad rail. Readings of the load and the corresponding depression were taken at regular intervals. Under a 7000-lb. load the new solid tire deflected 0.7 in., but the corresponding 8-in. pneumatic tire deflected 3.4 in., or 4.9 times as much. However, for consideration of tire effects upon the highway, the worn solid tire should be the one considered. The three-quarter-worn solid tire about 1 in. thick depressed only 0.3 in. under a 7000-lb. load and the corresponding pneumatic tire depressed 3.4 in., or slightly more than 11 times as much. These same tests were repeated with a 12-in. solid tire against a 12-in. pneumatic tire. It was found that practically the same proportions hold.

A. F. Masury has taken advantage of the Novograph motion-picture machine to study the depression of pneumatic as compared with solid truck tires. The very ingenious method of having the trucks leap into the air and come down against the pavement was used. This without doubt introduces the most extreme stresses. In his conclusions[2] he compares two trucks of the same capacity and design, one equipped with presumably new solid tires and the other with pneumatic tires. Each had the same amount of load and each attained the same speed at the leap. The force with which the solid-tired truck struck the ground was 14,336 lb. for unsprung parts as against 4624 lb. with the pneumatic-tired truck. The force from the sprung parts was 13,014 lb. for the solid and 9282 lb. for the pneumatic-tired truck. The deflection of the pneumatic was 4.5 times that of the solid tires. This checks closely with the Goodyear company test showing 4.9 times as much deflection for a pneumatic tire as for a new solid tire. If Mr. Masury had made his trials with worn solid tires, he would, no doubt, have found that the pneumatic tire depresses about 11 times as much as the worn solid tire; therefore, the worn solid tire introduces enormous stresses into the structure of the highway pavement.

Still another class of tests is now in process and has an important bearing on this question. The tests are being conducted by the Bureau of Public Roads of the Department of Agriculture, under the direction of A. T. Goldbeck and E. B. Smith. They are made by running various trucks over a certain stretch of highway and artificial means are provided for causing the wheels to drop given distances. The force of the impact on the road is measured by the compression of standardized copper cylinders. Curves plotted from the data obtained in these tests are shown in Fig. 3. In all but one case the test was made on the same type of truck equipped first with solid and then with pneumatic tires. In the test on the 5-ton capacity truck a chain-driven solid-tired truck was run against a truck of the same make equipped with pneumatic tires but driven by a double-reduction gear. This introduced some difference in the weight of unsprung parts, but it was noted in each case. The conclusions that can be drawn from these tests are that

(1) With solid tires the force of the impact increases rapidly with an increase in speed; whereas with pneumatic tires the force increases only slightly with a large increase in speed
(2) Pneumatic tires give only one-third to one-fifth the impact force of solid tires
(3) A 5-ton truck on pneumatic tires can travel 24 m.p.h. with the same impact effects that a solid-tired truck having new tires will cause at 8 m.p.h.
(4) The value of the impact force with pneumatic tires is only from 1000 to 1500 lb. greater than the wheel load. With the worn solid tire the impact force became 38,000 lb. greater than the wheel load of 7000 lb. at a speed of only 10 m.p.h. over a drop of 2 in., in the test of a 3-ton truck

It appears, therefore, that we have found definitely the cause for the destruction of our highways. Without doubt, if the highway engineer is asked to design a pavement to carry solid-tired trucks, he necessarily must consider the forces introduced by the worn solid tire as the maximum force which the pavement must withstand. Also, if he designs a highway to carry pneumatic-tired vehicles, he should be able to design one that will cost much less money than one designed to carry solid-tired vehicles. I have serious doubts if this country, wealthy as it is, can afford to build properly the highways required for carrying motor trucks equipped with solid tires, especially when the enormous stress introduced by the worn solid tire is taken into consideration.

The Pneumatic Truck Tire

In regard to the state of development of the pneumatic truck tire and the average mileage secured by its users, Table 1 gives an analysis of 500 trucks and covers the average mileage secured.

TABLE 1—PNEUMATIC TRUCK TIRE CARRYING CAPACITY AND MILEAGE[3]

Size of Tire, in.	Carrying Capacity, lb.	Average Mileage
6	2200	14,026
7	3000	14,791
8	4000	12,782
9	5000	12,028
10	6000	11,317
12	9000	Still experimental

[3] Analysis of 500 truck performances.

It is generally conceded that pneumatic truck tires will not withstand overloading successfully. The matter of introducing the larger sizes, 10 and 12 in., introduces new problems, including those of service, availability of necessary air pressure and the disposition of the driver in the matter of taking care of the equipment. The 10-in. tire is giving very satisfactory service where it is properly handled, although it is a heavy and costly tire. The 12-in. tire is giving very gratifying results from the mileage standpoint, but it appears to be too high a tire, too heavy and too costly to give general satisfaction. On this account we feel that there is good reason for experimenting with the application of four small-size tires to replace the two 12-in. rear tires. Since there are many objections to the use of dual pneumatic tires in the sizes above 5 in., applying the tires in tandem seemed advisable. We therefore constructed a motor truck throughout, to determine the practicability of this kind of tire application it is shown in Fig. 4. This is a pneumatic-tired truck of 5-ton capacity. Brief specifications are

[2] See The Journal, July, 1920, p. 96.

FIG. 4—PNEUMATIC-TIRED TRUCK OF 5-TONS CAPACITY IN WHICH TWO 12-IN. REAR TIRES HAVE BEEN REPLACED BY FOUR SMALL-SIZE TIRES

given below. The mileage obtained from the different trucks built is given in Table 2.

Wheelbase—From the center of the front wheel to the center between the two tandem rear wheels, 180 in.
Tires—Pneumatic all around, size 40 x 8 in.
Engine—Four-cylinder 5 x 6 in. Hercules; Model T-3-40 hp. (N. A. C. C.); 3200 lb.-in. torque at 1200 r.p.m.
Ignition—Philbrin
Radiator—Modine Spirex.
Transmission—Brown-Lipe, Model 60-UPP and Auxiliary
Clutch—Brown-Lipe, Model 60, multiple-disc
Speeds—Six forward; two reverse
Gear Ratios—

Low, 82.0 to 1	Fifth, 10.0 to 1
Second, 35.7 to 1	Sixth, 5.8 to 1
Third, 23.2 to 1	Low reverse 99.5 to 1
Fourth, 20.1 to 1	High reverse 28.4 to 1

Rear Axles—Two, Standard Parts; Model 603; worm drive arranged in tandem; ratio 5.8 to 1. Equipped with four 21-in. diameter brakes of 5½ in. width; in pairs, 2¾ in. wide.
Fuel and Oil Capacity—Gasoline, 67 gal.; oil, 10 gal.
Turning Radius—35 ft.
Chassis Weight—8500 lb.
Normal Speed—25 m.p.h.
Maximum Speed—In tests under full load on a level road, 45 m.p.h.
Body—Haskelite plywood, weight 2000 lb. Loading compartment 15 ft. long, 6 ft. high, 7 ft. wide; contains sleeping compartment, toolbox and compartment for two spare tires and other parts; sides and partitions, 5/16 in. thick; roof ⅛ in., covered with 4-oz. duck

TABLE 2—SIX-WHEEL TRUCKS BUILT AND MILES OPERATED[4]

Truck No.	Miles Operated
X-1	12,000
X-2	10,000
X-3	5,000
X-4	900
X-5	Now being built

[4] The chain, worm and internal-gear axles of these trucks are now being tested.

This new type of truck is offered as a solution of the problem of suitable pneumatic tires on trucks of 5-ton capacity and upward, where

(1) Greater speeds than those advisable with solid tires are desired
(2) Greater protection to the merchandise carried is necessary
(3) High speeds and heavy loads will not work injury to the roads
(4) The comfort of the driver is a consideration
(5) A low center of gravity is desired
(6) Safety demands additional braking capacity
(7) Bad roads now interfere with economical operation
(8) Simplicity of tire change, low tire cost, economical operation and a broadening of the field of highway transportation are necessary

SPRING SUSPENSION AND STEERING

Two types of spring suspension are being used in our experiments. The one shown in Fig. 5 consists of a single spring on each side of the chassis; it is inverted and pivoted to the chassis frame and rests on spring bolts in brackets fastened to the axle housing. The axles are held in place by crossed tie-rods, which permit the lengthening and shortening of the spring. This type is giving satisfactory results.

The type shown in Fig. 6 consists of two springs on each side of the chassis frame. These are bound together and pivoted to the chassis frame. This construction does not involve the tie-rods but does require that the springs be fastened pivotally to the axles, to permit the necessary flexibility for the latter when an irregular road contour is encountered. This general method of pivoting the rear-axle assembly gives unusually good riding qualities.

How the truck steers around corners is hard to explain. This can be partially understood from Fig. 7, which shows that the high pneumatic truck-tire section permits the tire to deflect sidewise and that it is thus allowed to take the curve gradually without slipping and wearing the tread. We have not worn out any tires on this six-wheel truck as yet, but the condition of the tires now in use indicates that we can expect 10,000 to 12,000 miles of service from the rear tires.

When operating this truck alone with a 5-ton pay load, a total weight of 21,000 lb., over the brick highway between Akron and Alliance, Ohio, a distance of 120 miles, the average speed was 23.9 m.p.h. and the average gasoline consumption 6 miles per gal. When operating this truck with a trailer attached as shown in Fig. 10, each vehicle being loaded with 5 tons and constituting a total pay-load of 10 tons or a gross load of 37,000 lb., over the same highway and a distance of 125 miles, the average speed was 16.8 m.p.h. and the average gasoline consumption 2.8 miles per gal.

These performances indicate good possibilities for attaining a 48-hr. motor-truck express service between Akron and New York City, the distance by highway being 500 miles. The present express rate for goods shipped

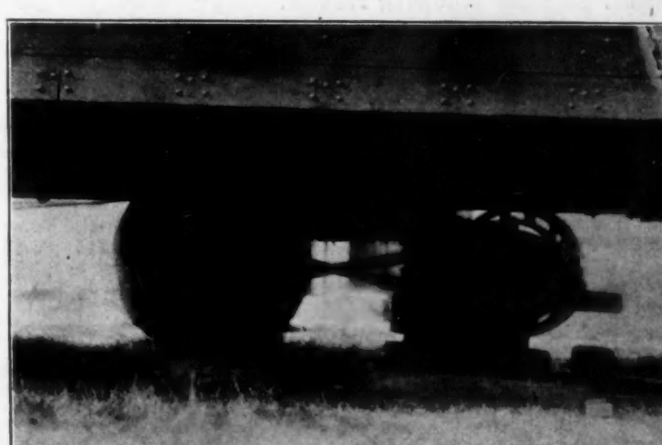


FIG. 5—A TYPE OF SPRING SUSPENSION CONSISTING OF A SINGLE SPRING ON EACH SIDE OF THE CHASSIS, THE SPRING BEING INVERTED, PIVOTED TO THE CHASSIS FRAME AND RESTING ON SPRING BOLTS IN BRACKETS FASTENED TO THE AXLE HOUSING

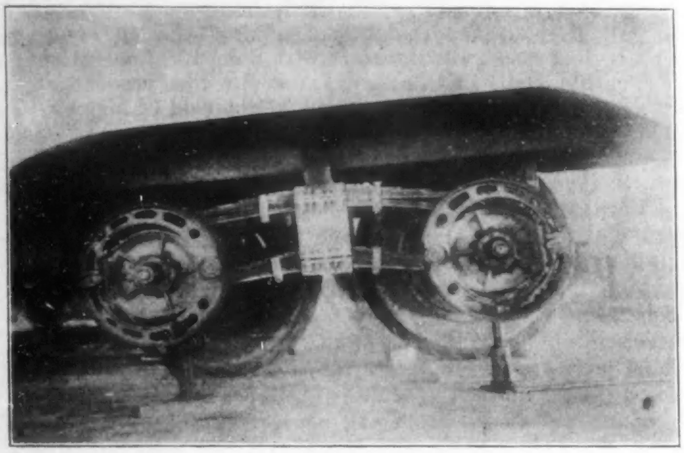


FIG. 6—A SPRING SUSPENSION CONSISTING OF TWO SPRINGS BOUND TOGETHER AND PIVOTED TO THE CHASSIS FRAME

from Akron to New York City is $2.84 per 100 lb., or $56.80 per ton. Therefore, a 5-ton truck that can operate within 56.8 cents per mile and average 20 m.p.h. can, at express rates, give better service than that of the railroad express company.

SUMMARY

(1) Past experience and recent tests prove that the solid-tired truck is an extremely uneconomical factor in highway transportation, from the fact that it is unquestionably destroying present expensive highways; and that it will destroy any highways constructed in the future, unless they are built about five times the present strength, at about three times their present cost
(2) Pneumatic truck tires are proving their practicability
(3) It appears possible to design a vehicle that will have many mechanical advantages and only require a pavement designed and built for carrying and withstanding the shocks of a loaded 9-in. pneumatic truck tire. This combination of vehicle and highway would permit a pay-load capacity of from 5 to 7 tons. Even with this heavy tonnage capacity this type of truck would have less of a destructive effect upon the highway than present light solid-tired trucks, and it would be very economical to operate from the standpoints of fuel consumption, tire, maintenance, and highway costs

Since the paper was presented, the six-wheel truck referred to has been tested by the Bureau of Public Roads with the following results:

FIG. 7—HOW THE HIGH PNEUMATIC TRUCK-TIRE SECTION PERMITS THE TIRE TO DEFLECT SIDEWISE, THUS ENABLING A TRUCK TO TURN CORNERS WITHOUT SLIPPING AND WEARING THE TREAD

(1) The impact delivered by the six-wheel truck loaded with a 6-ton pay-load was equal to the impact delivered by an ordinary 2-ton truck having a 2-ton pay-load
(2) The bearing pressure upon the highway pavement is at a maximum under each of the rear wheels, giving a soil pressure of approximately 3 lb. per sq. in., maximum, with a 6-ton pay-load as against 6 lb. per sq. in. for an ordinary 5-ton truck with a 5-ton pay-load
(3) The maximum impact delivered by the six-wheel truck with a 9-ton pay-load was approximately 10,000 lb., as against a maximum blow of possibly 70,000 lb. delivered by an ordinary 5-ton truck with a 7½-ton pay-load

THE DISCUSSION

CHAIRMAN G. W. SMITH, JR.:—How about the shock effects on the springs themselves?

W. M. NEWKIRK:—I think that the six-wheel construction should be easier on the spring than the usual construction on the four-wheel trucks.

CHAIRMAN SMITH:—I had in mind the abnormal obstruction which, as Mr. Templin states, causes a 45,000-lb. impact.

MR. NEWKIRK:—The spring does not get that amount of shock. I understand that is the measure of the impact between the tire and the road.

CHAIRMAN SMITH:—But the difference in the impact of the load would be very considerable, due to the spring.

MR. NEWKIRK:—It is the actual force exerted on the road surface which is considered. The shorter the space is in which that force is counteracted, the greater the pressure is. I understand that this force can be measured fairly accurately by the method of compressing those copper cylinders.

CHAIRMAN SMITH:—The matter of work done enters the problem, as well as that of force.

MR. NEWKIRK:—It is entirely a matter of work done. The effective pressure on the road surface, at the instant of passing an obstruction, is made up principally of two factors, the static load and the impact of the unsprung parts of the car. This latter should be thought of as "work" rather than pressure. We have a mass which must either be suddenly lifted, if passing over an obstruction, or whose vertical motion must be suddenly stopped, if dropping over the edge of a hole. At the instant of contact, the road surface pressure will increase, the amount of increase depending very largely upon the yielding character of the tires and the road surface. The greater the compressibility of the tire is, the greater the distance is through which the vertically moving parts will be acted upon by the force required to bring them to rest and, consequently, the smaller this force will be. The relative incompressibility of solid rubber tires as compared with pneumatic tires makes it self-evident that with pneumatic tires the pressure effect upon the road must be decidedly less harmful.

The impact of the sprung load is not a serious matter, as the springs under anything like normal conditions will always yield so freely that but little increase in road pressure can be produced. As a general proposition, the more flexible the springs are, the less the road pressure effect will be.

A. K. BRUMBAUGH:—Mr. Masury's figures appear optimistic because he was dealing with forces due to impact and measuring them by a moving picture machine set some distance away. What sort of ground or under what condition did Mr. Masury make his tests? Were they made on a non-compressible surface, or were they made on earth?

E. W. TEMPLIN:—I do not know. His report mentions the compression of the tire as well as the depression in the pavement.

MR. BRUMBAUGH:—I believe 14,336 lb. was specified as the striking force of the solid tires. How can he be so exact? In connection with the figures given for the solid-tired truck, undoubtedly the impacts are far greater than with the pneumatic tires, but the figures predicated on too bad a road. If the depressions in roads are measured, it will be found that they are much less than they appear to be. The 2-in. drop represents a rather healthy hole in the road; some are deeper, but not all roads have 2-in. holes. We have some far better roads than that. The utmost destructive effect on roads is caused by the concentrated wheel load which is not helped out by either the solid or the pneumatic tire. All the roads were broken to pieces about the spring of 1918. Roads laid with 8 to 10 in. of concrete that was not reinforced were broken. Invariably, on the hillsides and at soft places, the breakage was due to the sub-grade of the road, and not to raveling effects or impact of tires. On every hillside, on which springs normally occur, and in places where through lack of men and funds it has not been possible to keep the ditches open, the roads have failed, there being a soft wet spot beneath the point of failure. Undoubtedly, a heavy raveling effect is caused by solid tires, but I believe that the pneumatic tire running at from 30 to 40 m.p.h. is not innocent of that effect either. When pneumatic tires are new and the lugs are on, they may not damage the road in this manner, but I believe there is a strong suction effect later which does cause raveling. I believe that there is very little more impact with solid than with pneumatic tires on an ideal road surface. On bad roads solid tires cause some additional impact and the pneumatic tire gives better results.

The matter of wheel load is a large factor, and is recognized by highway engineers first in building roads of reinforced concrete. Roads surfaced with large reinforced-concrete slabs hold together better under an improper sub-grade condition. Engineers recognize wheel load in the limitation of the total weight that is allowable on four wheels; that is 28,000 lb. In Pennsylvania it is 26,000 lb. and roads built with 8 to 10 in. of plain concrete not reinforced will not stand up, unless the sub-grade is in perfect condition, the ditches open and the road adequately drained. These roads are torn to pieces by excessive loads. In addition to load, on an ordinarily poor road, if the truck mires and the driver has power enough to rotate the rear wheels, he will put only one chain on, if he thinks he can avoid using two, and try to dig out in that way; finally, he may be forced to use some other means to get out. That is typical of the road between Philadelphia and New York City, which probably carries heavier truck traffic than any other road in the country. The traffic is enormous and this road is torn to pieces by heavy motor trucks, as soon as it becomes somewhat bad or soft, either by sliding off to one side of the road or by digging holes right in the road.

CHAIRMAN SMITH:—Mr. Brumbaugh makes three points; that damage due to loads is a matter of sheer weight in many cases, that pneumatic tires have a raveling effect due to suction, and that the 2-in. arbitrary fall mentioned in Mr. Templin's paper is rather a pessimistic view to take of general conditions. Incidentally, a certain amount of damage is due to the slippage of wheels and to tire chains.

G. H. WOODFIELD:—I think that Mr. Templin did not attempt to use 2 in. as the average fall; he used that distance simply to point out the relationship between solid and pneumatic tires.

MR. TEMPLIN:—Referring to the 45,000-lb. impact for the 2-in. drop in Fig. 5, note that for 1 in. the impact value goes up to 27,500 lb., which is practically 20,000 lb. above the static wheel load. That will give a basis for judging what value the civil or the highway engineer should take in designing pavements. Notice also that the maximum value for the solid tire occurs at about 11 m.p.h. The pneumatic tire was run up to 17 m.p.h. and the impact value is scarcely above the static wheel load. These tests are not as yet completed. These data are for a 3-ton truck; the data for a 5-ton truck with the tires worn down will be equally interesting. The figures given are for a 5-in. dual solid and for a 9-in. pneumatic tire.

MR. BRUMBAUGH:—What is the area of the tire on the ground?

MR. TEMPLIN:—The area of the 9-in. pneumatic tire on the ground is 50 sq. in. for each tire; the area of the solid tire no doubt would have been about 25 sq. in. Solid tires average practically one-half the area of the pneumatic tires, on the ground.

MR. BRUMBAUGH:—Were all the measurements in the tests made by the copper-cylinder method?

MR. TEMPLIN:—Yes.

MR. BRUMBAUGH:—What total amount of compression is involved in the copper cylinders? Is it large enough to take care of any moderate difference of impact? I judge that it is a very small fraction of an inch, so that a few thousandths of an inch would correspond to a great many thousand pounds of impact.

MR. TEMPLIN:—These cylinders are calibrated very carefully.

MR. BRUMBAUGH:—Regarding uniform composition of the copper?

MR. TEMPLIN:—Yes.

MR. BRUMBAUGH:—Are they calibrated by impact?

MR. TEMPLIN:—Yes.

MR. BRUMBAUGH:—Even at 45,000 lb., that is a severe blow. If they have only 25 sq. in. per tire, that would give a 50 sq. in. total on the ground, or certainly not under 45 sq. in. Was 45,000 lb. the value stated for one wheel?

MR. TEMPLIN:—Yes.

MR. BRUMBAUGH:—Certainly there must be more than 25 sq. in. of tire surface on the road, with a 45,000-lb. impact.

MR. TEMPLIN:—That applies to a worn solid tire having only about 1 in. of rubber on it.

MR. NEWKIRK:—Undoubtedly that amount of impact is terrific.

MR. TEMPLIN:—Concrete pavements begin to fail at the joints. Even a ¼-in. drop will start the joint chipping off at the edges. As that drop increases to 2 in., even if it does not become greater, that is enough to break the joint down.

MR. BRUMBAUGH:—I have watched concrete road failures. It will be found that 90 per cent of them are due to a total breaking up of the road. If it is a well-laid concrete road, when it fails this is usually caused either by temperature cracks or cracks due to the failure of the sub-grade, although there is some raveling at the expansion joints. Once the sub-grade fails, it just breaks to pieces. On the Pennsylvania and Maryland roads on every hillside the concrete is being broken into chunks. Generally, the surface is good; there is no evidence of small detail failures throughout the surface, except on the

(*Concluded on page 226*)

Spectroscopic Investigation of Internal Combustion

By THOMAS MIDGLEY, JR.[1] AND W. K. GILKEY[2]

ANNUAL MEETING PAPER *Illustrated with* DIAGRAMS AND PHOTOGRAPH

THE paper is designed to familiarize automotive engineers with the general subject of spectroscopy, pointing out the various methods that can be employed to determine the actual instantaneous pressures obtained in normal combustion, the temperature-time card of the internal-combustion engine and the progress of the chemical reactions involved in normal and abnormal combustion.

The subject of spectroscopy is outlined and explained, illustrations being presented of different types of spectra, and spectroscopes and their principles are discussed.

The remainder of the paper is devoted to an outline of what the spectroscope can reveal about the nature of combustion.

THE spectroscope has contributed more knowledge to man concerning the nature of the universe in which he lives than any other single piece of scientific apparatus. It is possible to determine by its use the velocity with which the heavenly bodies are either approaching or receding from the earth, the temperatures of these bodies, the elements of which they are composed and the state of matter in which these elements exist. For example, the element helium was discovered in the atmosphere of the sun some 27 years before it was found to be existent on the earth. The spectroscope has played an even more important part in the realm of the infinitesimal. For example, it is possible to detect in the flame of a bunsen burner 1/80,000,000 mg. of lithium, an amount that defies all other methods of detection. Moreover, the X-ray spectroscope has given us an entirely new conception of the constitution of matter. With such an instrument available to the automotive engineer, it is remarkable that he has never made use of it to study the most fundamental problem of internal-combustion engineering; namely, internal combustion itself.

It is not the purpose nor is it within the scope of this paper to present data that will settle definitely any of the disputed points concerning combustion. This result can be accomplished only after years of serious research by many investigators. It is our purpose, rather, to present to the automotive engineer a brief outline of spectroscopy and to point out the various methods that can be employed to determine the actual instantaneous pressures obtained in abnormal combustion, the temperature-time card of the internal-combustion engine and the progress of the chemical reactions involved in normal and abnormal combustion.

SPECTROSCOPY

Spectroscopy is the resolution of light into its component parts and the study of these parts. As an example, of two different lights, both may appear white to the eye; but the spectroscope may reveal that one as a hot incandescent solid and that the other is a gas electrically excited.

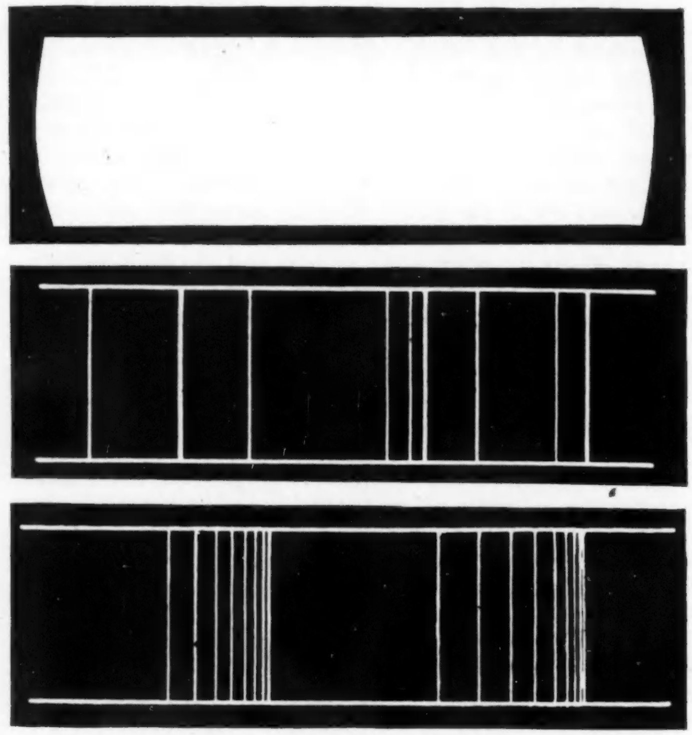


FIG. 1—EXAMPLES READING FROM THE TOP DOWN OF THE CONTINUOUS, LINE AND BANDED OF FLUTED SPECTRA

The three distinct kinds of spectra are the continuous spectrum, the line spectrum and the band or fluted spectrum. An electric light gives a continuous spectrum; that is, one containing all wave-lengths and having no discontinuities. At one end it is red; the red color blends into orange, the orange in turn blends into yellow, the yellow into green, and so on. On the other hand, a mercury-vapor lamp gives a spectrum consisting of only a few lines, of which two yellow ones, close together, a green and a violet, are most easily seen. If we examine the spectrum given by a carbon arc, we find that it is continuous with bright flutings superimposed at certain places. Fig. 1 shows examples of continuous, line, and banded or fluted spectra in the order named commencing at the top of the illustration. Continuous spectra are typical of hot incandescent solids and liquids. Line spectra are given by a spark passing between metals or by an elemental gas at low pressure and electrically excited. Fluted spectra are given by gaseous compounds under various conditions.

There is another type of spectrum that may be mentioned, although it probably has little bearing on internal-combustion work. When a white light is caused to

[1] M.S.A.E.—Chief engineer, fuel research section, General Motors Research Corporation, Dayton, Ohio.

[2] Research engineer, fuel section, General Motors Research Corporation, Dayton, Ohio.

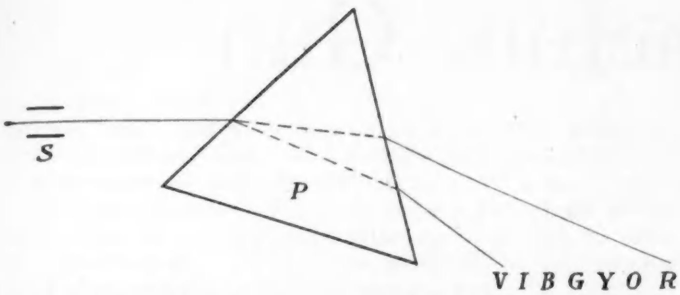


FIG. 2—DIAGRAM ILLUSTRATING THE SIMPLEST FORM OF SPECTROSCOPE

pass through a gas that fills the space between it and the slit of the spectroscope, a spectrum is obtained that is continuous except for a number of dark lines crossing it. These dark lines have the same wave-lengths as those that the gas would emit if electrically excited in a nearly evacuated tube. The dark lines indicate that the gas has absorbed the light that has the same wave-lengths as the gas would emit if it were made the source of light. Such spectra are called absorption or dark-line spectra. The continuous spectrum from the sun is crossed by thousands of these lines, called Fraunhofer lines from the name of their discoverer. They indicate that the atmosphere of the sun is composed of gases and the vapors of metals that are cooler than the solid body of the sun, and that these gases and vapors have absorbed from the original light those colors having wave-lengths characteristic of the emission spectrum of these substances. For this reason, it is easy to analyze the atmosphere of the sun by the spectroscope.

SPECTROSCOPES

An instrument for producing a spectrum and investigating it is called a spectroscope. The simplest form of spectroscope consists of a glass prism that receives from a narrow slit the light to be investigated. When it emerges from the prism, this light is spread out as is shown in Fig. 2, in which *S* is the slit, *P* is the prism, and the letters *V I B G Y O R* stand for violet, indigo, blue, green, yellow, orange and red light, respectively.

Red light has the longest and violet light the shortest wave-length of the visible spectrum. The visible spectrum extends from 0.40 micron to 0.76 micron; 1 micron equals 0.001 mm. But beyond the violet is the ultra-violet, which extends to 0.10 micron; and beyond the red is the infra-red, which extends to 200 microns; and far beyond this even are waves of the same character, differing only in that they have longer wave lengths.

A prism is not the only means of separating light into its component parts. Several other methods are available, all of which have their limitations. The diffraction grating is the only one of these that need be considered here. A grating is a piece of metal or glass on which several thousand lines per inch have been ruled with a diamond point. The grating used in our work is of speculum metal ruled with 15,000 lines per in. A grating acts in a manner similar to that of the prism, producing the same kind of spectrum except that the grating can spread light out into a spectrum that is several times as long as that formed by a prism. Fig. 3 is a diagram of the optical system of one of our spectroscopes that was designed and built by Prof. H. C. Lord, of Ohio State University. Fig. 4 is a photograph of this spectroscope. Note that this instrument has both a prism and a grating, and that these are arranged so that the effect of one is added to that of the other.

[3] See Spectroscopy by E. C. C. Baly, p. 636.

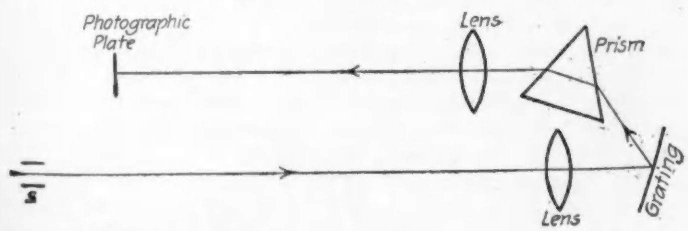


FIG. 3—DIAGRAM OF THE OPTICAL SYSTEM OF THE SPECTROSCOPE USED BY THE AUTHOR

SPECTROSCOPIC ANALYSIS

Three things about an explosion in an engine can be determined with a spectroscope; that is, the pressure, the temperature and the chemistry of the combustion. It should be borne in mind that it is only possible for the spectroscope to do this because it has no moving parts and makes use of light alone, which has no inertia; so, any combustion condition is instantaneously recorded.

The pressure can be determined by the shift of the sodium *D* lines that is due to pressure. This pressure-shift has been thoroughly investigated by Humphreys, who found that a rise in pressure of 12 atmospheres increased the wave-length of these lines 0.108 Angstrom unit (1 Angstrom unit $= 10^{-7}$ mm.), and thus shifted them toward the red end of the spectrum.[3] There is always enough sodium in the air entering the cylinder to give these sodium lines; hence, it is only necessary to photograph a stroboscopic spectrum of the light coming from the engine to obtain a record of any shift of the sodium lines. Since Humphreys proved that the shift is directly proportional to the absolute pressure, the pressure can be calculated from the amount of this shift. Fig. 5 shows what might be expected on a photograph if a very high pressure existed for a third of the combustion stroke.

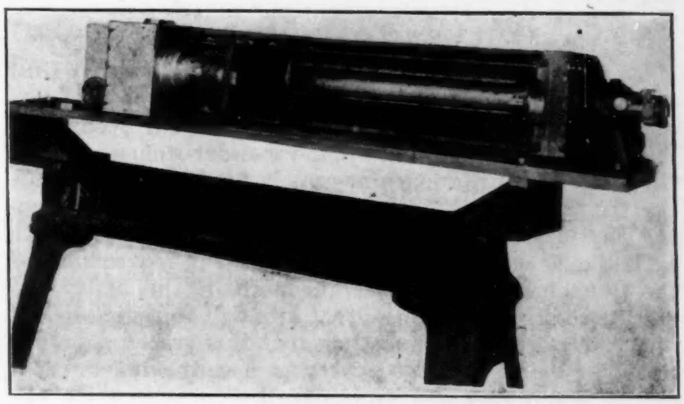


FIG. 4—PHOTOGRAPH OF THE SPECTROSCOPE SHOWN IN DIAGRAMMATIC FORM IN FIG. 3

The temperature can be determined in accordance with Wien's law, which states, for a perfectly black body, the wave-length of maximum energy is inversely proportional to the absolute temperature. Unfortunately, except for extremely high temperatures, this maximum is in the infra-red where observation is difficult on account of the limitation that the light cannot be allowed to pass through glass because it absorbs the infra-red rays. It is necessary, therefore, to use a quartz window in the cylinder and a rock-salt prism in the spectroscope, and to do the focusing by spherical mirrors instead of lenses. The spectral rays are received on a thermopile that actu-

(Concluded on page 222)

A Super-Machine-Gun

A MACHINE-GUN far more powerful than any other similar weapon heretofore used has been developed recently for army service. This is known as the Browning 0.50-caliber machine-gun. It is without doubt the most important and interesting development in the small-arms field since the world war, and perhaps one of the most interesting in the whole field of ordnance. In August, 1914, the caliber of the standard machine-gun of each nation was the same as the caliber of the infantry weapon of that nation, and in most instances they fired identically the same ammunition. The principal rôle assigned to machine-guns at that time was that of supplementing rifle-fire against targets assigned to the infantry and the cavalry.

One of the first departures from the prewar conception of the proper use of the machine-gun was its use in aerial combat, both defensively against attacking opponents in the air and offensively against enemy airplanes and ground targets. At the same time their use from the ground against low-flying airplanes was being developed and strenuous efforts were made to improve their effectiveness when used either from the ground or in the air against aerial targets.

Tracer and Incendiary Bullets

To make the aiming of the machine-guns used against such targets easier and more certain, the expedient was adopted of using a hollow bullet containing a chemical mixture that is ignited by the powder charge in the cartridge when the machine-gun is fired and burns during the flight of the bullet with a bright light. By loading the belts or magazines so that every fifth or sixth cartridge is one having a tracer bullet, it is possible for the gunner actually to see the path of the bullet and quickly to direct his gun so that hits will be registered on the target. At the same time that this tracer ammunition was being developed for war use, the inflammable nature of aircraft and of captive balloons used for observation purposes brought home the desirability of devising ways and means of setting them on fire. To meet this requirement, incendiary ammunition was developed. This ammunition consists simply of a hollow bullet filled with phosphorous that burns during the flight of the bullet, and will set fire to inflammable material with which it may come into contact.

The small caliber of all machine-guns used up to this time limited the effectiveness of these special types of ammunition very materially, but the French had a cartridge 11 mm. (0.433-in.) in caliber that had been developed in 1874 for use in the French rifle of that caliber, and an investigation indicated that Vickers machine-guns of British and American calibers (0.303 and 0.300 in.) could easily be changed so as to fire this cartridge. The bullet of this cartridge is approximately 50 per cent greater in diameter than the bullet of the 0.303 and 0.300 cartridges, which made possible the design of a more effective incendiary bullet. This, accordingly, led to the development and use of the 11-mm. (0.433-in.) machine-gun, greater in caliber than any theretofore in general use in the war.

Several months after active work was begun on the 0.50-caliber machine-gun, a new cartridge designed and used by the Germans made its appearance on the western front. This cartridge had a bullet approximately ½ in. in caliber, and was used in combating tanks that carried considerable armor. The weapon from which the cartridge was fired is a single-shot rifle, in every way similar to the Mauser rifle with which the German infantrymen were armed, but of necessity larger in every respect. The ammunition, as designed, was very well thought out, and tests indicated that it would penetrate approximately 1 in. of good armorplate. The bullet was streamline in form and weighed 51.4 drams. A thorough investigation of this German cartridge made it desirable to redesign the 0.50-caliber cartridge previously developed by us, in order that our ammunition might at least be the equal of any other ammunition known. This resulted in a much more powerful cartridge, which in turn made necessary a slightly heavier gun. The complete 0.50-caliber cartridge weighs approximately 1890 grains. It is loaded with approximately 235 grains of powder, and its bullet weighs 804 grains. It takes about 23 0.30-caliber cartridges to weigh 1 lb. and only four 0.50 caliber cartridges. In other words, the 0.50-caliber cartridge is six times as heavy as the service cartridge. As soon as the design of the improved type of cartridge had been determined upon, a definite and specific program for the completion of the development of the machine-gun itself was laid down. This involved the design and manufacture of a limited number of each of three distinct types of gun; namely, the water-cooled type for use on the ground against ground targets, the anti-aircraft-tank type for use on the ground against aircraft and for mounting in tanks and the aircraft type for mounting in airplanes for use against ground targets or enemy aircraft. The design of these three has been carried along together and an endeavor made to have as many parts as possible common to all types. Samples of all three have been delivered and tested, and preliminary trials indicate that the program has been a success in every way.

The Browning 0.50-caliber machine-gun as finally perfected is a recoil-operated weapon, is belt-fed and fires at the rate of approximately 550 shots per min. Its operating principle is the same as that of the 0.30-caliber Browning machine-gun. The water-cooled gun weighs approximately 66 lb. without water and 82 lb. with the water-jacket filled. The water-jacket has a capacity of 8 qt. and the water reaches the boiling-point after 300 rounds of continuous firing. The gun is mounted on a tripod that weighs 80 lb. When fired, the gun imparts a muzzle-velocity of 2500 ft. per sec. to the 804-grain bullet and its maximum range is 9000 yd. Fig. 1 gives a graphic comparison of the trajectories of the 0.50-caliber bullet fired from the water-cooled machine-gun and the ordinary 0.30-caliber 150-grain bullet in regular use in our service.

The high state of development and the efficiency of this weapon, as well as the complexity of the design problems are obvious. The Browning anti-aircraft 0.50-caliber machine-gun develops 204 hp., or 1 hp. per 0.255 lb. The Browning 0.50-caliber water-cooled machine-gun develops the same horsepower, or 1 hp. per 0.294 lb. of weight. Weight for weight, the Browning 0.50-caliber water-cooled machine-gun develops more than 15 times the energy of the Liberty engine.

The field of usefulness of this weapon is very large, but probably the most important of all is its use from the ground against aerial targets, that is, for anti-aircraft defense purposes, and in view of recent tests that

demonstrate the enormous destructive power of bombs dropped from aircraft, it might be well to draw particular attention to its possibilities in this connection. This weapon is capable of projecting bullets into the air, each weighing 1/9 lb., at the rate of 550 to 600 per min. or 10 per sec. The initial velocity is such that the effective range against aerial targets is estimated to be at least 1500 yd. and one hit on a vital part of an airplane at this range will be disastrous. This means that in maneuvers, such as bombing, directed against objects on the ground that are properly protected by these guns, it will be necessary for an airplane to fly above this altitude to keep out of range, and this in turn means much less effective work. On account of its rapidity of fire and its high velocity, it is confidently believed that this weapon is by far the most effective weapon that has been developed to date for use from the ground against attacking airplanes.—Col. Herbert O'Leary in *Army Ordnance.*

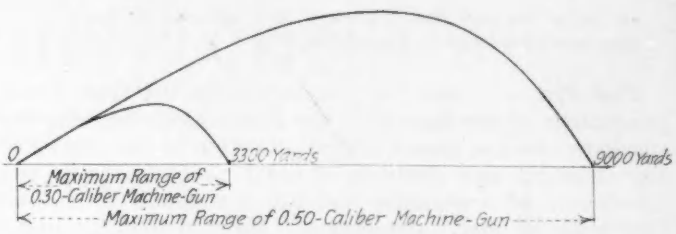


FIG. 1—DIAGRAMMATIC COMPARISON OF THE TRAJECTORIES OF THE 0.30 AND 0.50-CALIBER BROWNING MACHINE-GUNS

CHICAGO AND MINNEAPOLIS MEETINGS

(*Concluded from page* 170)

much lower than those in the foreign countries I have named, but they have been increased over 100 per cent and are now higher than those of our competitors. We have had also the advantage of better and more economical facilities for handling the grain in the country and at terminals, but a great change is taking place in this respect. As fine terminals as can be found anywhere in the world have been completed recently in Buenos Aires. Lines of country elevators similar to our own are to follow. Terminals and country elevators are being constructed in South Africa, promoted and financed by British capital, to take care of the increasing production of grain in that country.

I believe that the railroads will never be able to make a rate on grain from the Middle West to the sea that will enable us to maintain our place in the world's market. We must have deep-water transportation from our Great Lakes ports to the ocean, and we should have it without unnecessary delay.

LACK OF IMPROVEMENT IN RAILROADING

During the past 20 years nearly every kind of industry has undergone tremendous changes, to keep abreast of the times. Has any one observed any particular change in railroad methods, or any new development in rail transportation, during that period? To my knowledge, there has not been a single improvement of any kind or a single change in method in railroading for more than 20 years. The railroad people say that their hands have been tied by the Government on the one side and by the Labor Board on the other, but I have never known of any railroad management of recent years taking the initiative in anything that would improve rail transportation.

The function of the Interstate Commerce Commission should be modified, the railroads being permitted to make rates subject to review by the Commission only in case of general complaint. This is the way in which the Commission worked for many years after it was created. The result was more satisfactory to the railroads and to the public than that had under the present method. The whole responsibility of management and operation should be on the railroad executives.

I quote from a recent bulletin of the *American Exporter:* "Bad as our export trade seemed during the past year, it was greater in both value and volume than in any prewar year. For the 10 months ending October 1921 our exports were 94 per cent greater than in the same period of 1913."

Our basic industry, agriculture, has started on the road to recovery, and the prospect for profits in farm operations is good. With the present prices of farm labor and implements and all that the farmer has to buy, I have never seen better chances for agriculture. The farmer who cannot make money under present conditions is not capable.

I believe that motorization of the farm has only started. A properly planned and intelligently operated motorized farm possesses decided economic advantages over the farm operated by draft animals, besides doing away with a large percentage of the drudgery that drives so many of the boys from the farm. It is pretty difficult to keep the boy on the farm driving horses. He feels when night comes that he has not accomplished much, and he has a half-day's work to do after he quits the field. With his tractor he feels that he has accomplished something. It is the psychology of the thing that will put power farming over in spite of all anybody can say regarding it. It has such a start that nothing under heaven can stop it.

I believe that there is room for improvement in the machines that are being supplied. You engineers can design and make machines that are more adaptable than those that are now on the market. More attention should be paid to the accessibility of the machine, and to simplicity of operation and handling, particularly the latter. Many of the machines that are out are mighty awkward machines. The manufacturers must recognize the responsibility that goes with the sale of machines. I think they have not always done that. They have sold machines in territories where they had to go many miles from the railroad station, with little regard to the requisites of service or to having spare parts available. Too many sales are made with little consideration as to the machine sold being suitable for the work in prospect. Considering the conditions under which he has labored, the progress the farmer has made in the use of power implements is wonderful. Some people harp on the inability of the farmer to operate the machines. I believe that no class that would take the kind of tractors that have been put out would make any greater success in the operation of them than the farmers have made. To me the most phenomenal thing about the whole situation is that so few of them fail with their tractors. Some records I gathered last year show that over 86 per cent of about 800 farmers who had been interviewed were operating their machines satisfactorily. Most of the other 14 per cent were not well pleased with their purchases but thought they had some advantages. Only 3 or 4 per cent condemned the machine. I think that is a remarkable record. I think that with the return of prosperity to agriculture that is sure to come sooner

or later we can look forward to a constantly increasing use of power implements.

Past-President Beecroft, in extending the thanks and salutations of the Society to the Minneapolis Section, the speakers and the guests, called attention to the fact that the members are studying current problems from the standpoint of economics, and are not bound up in the four walls of their laboratories. He said that the paramount duty incumbent upon engineers today is to get out into the field and study the conditions there. He continued:

> We should eliminate the word "pessimism" from our vocabulary in these days. It is abused. So is the word "optimism." Man can never attain the stature for which he was intended if he is always placed in beds of roses and lives in days of expansion and optimism. These are the grandest days that were ever lived. Who would want to live in this world if we had say 40 years like 1918, 1919 and 1920? These may be men-trying days, nerve-trying days, but surely they are not pessimistic days. They are days when we must get out and study the problems first-hand.
>
> The automobile, the truck, the tractor and the airplane are prime essentials of civilization today. It is said that we must have, first, food, then shelter; then, clothing. But what is it that knits all of these together? It is transportation. It has been made plain here tonight that one of our great problems consists of the evils that have been tied around transportation as we know it today. I think that those great arterial aspects of transportation, the truck and the tractor, will be able in great measure to solve the situation. But we must look upon them sanely.
>
> I have no patience with those people who want to call the automobile in any of its useful fields, such as those connected with farming and many other phases of life, a luxury; it does not exist as that; it is one of the great essentials of life. In these days let us be sure that we look at the matter in that light. Who would want to live on the farm without modern means of transportation?
>
> ESSENTIALS OF FARM LIFE
>
> Mr. Record referred to the Argentine. I had the opportunity of crossing that country in 1916. One of the saddest memories of my life is agricultural Argentina. In that huge expanse of territory the country people are a century behind the city people. I have no sympathy with those who want to keep anything agricultural behind the times. The agricultural people of this Country must walk side-by-side with the city people. We want them to have automobiles. We want them to have motor trucks when they are used economically. We insist that they have tractors when they are applied successfully and used economically. We want them to have the other things that make life a pleasure, that make life on the farm as comfortable as it is in the city. Only when we have life on the farm as it is in the city will we in this Country speak as a united people, as a homogeneous people, which we want to be.
>
> Our Society is doing and has done a great work, and will continue to be a worthwhile Society only in proportion to the character of the work it does. We as a people, we as an industry, we as a Society will be remembered by the character of our work, by the spirit that we put into it, by the sacrifice that we make in our every act.
>
> In these days the one thing we must do is to dedicate ourselves to the work of readjustment. During the war the Allies settled down to the business of war. In 1915 and 1916 we could not understand how they were getting along, but to them it was perfectly natural; they said, "Our business is war and we are carrying it on." Is not our business now readjustment? Let us hold high the torch of personal sacrifice, that torch of service. If we, as a united Society, as a united industry, as a united people, keep that ideal before us, we shall succeed.

SPECTROSCOPIC INVESTIGATION OF INTERNAL COMBUSTION

(*Concluded from page* 219)

ates a very sensitive galvanometer, and the wave-length corresponding to the maximum deflection on the galvanometer gives a means of calculating the absolute temperature existent at that time. By again using a stroboscope to regulate the time for the readings, we believe it possible to derive temperature-time cards of the power stroke.

The chemical changes occurring during combustion can be investigated by the bands in the spectrum due to carbon monoxide, carbon dioxide, water vapor and the like. Each compound has its characteristic spectrum, and the successive appearance and disappearance of these lines should yield valuable information on the nature of the combustion. This is, perhaps, the most difficult of the three problems, because these lines are very faint; in fact, they are so faint that we have observed any one of them only a few times, and we do not seem to be able to duplicate them. However, the behavior of the continuous spectrum from this standpoint is interesting for the reason that it tells us a great deal about how the free carbon behaves during combustion.

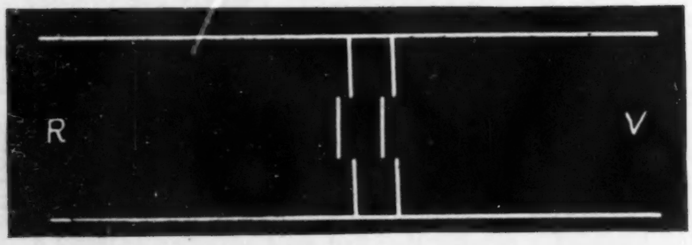


FIG. 5—PHOTOGRAPH OF A STROBOSCOPIC SPECTRUM OF THE LIGHT COMING FROM AN INTERNAL-COMBUSTION ENGINE CYLINDER WHERE A VERY HIGH PRESSURE EXISTED FOR A THIRD OF THE COMBUSTION STROKE

The study of the combustion of compressed mixtures of gasoline and air as it occurs in engines is in its infancy. The knowledge that we now have on this fundamental process is very limited, and many of the ideas that are held in regard to combustion are necessarily of a hypothetical nature. For the accurate study of the nature of combustion, which is a chemical reaction that occurs very rapidly and at high temperatures, instrumentation is necessary. In this connection the spectroscope offers great promise as a means of investigating the character of combustion reactions in internal-combustion engines.

ACTIVITIES OF THE SECTIONS

Secretaries of the Sections

BUFFALO SECTION—C. A. Criqui, chairman, Sterling Engine Co., Buffalo
CLEVELAND SECTION—E. W. Weaver, 5103 Euclid Avenue, Cleveland
DAYTON SECTION—R. B. May, Dayton Engineering Laboratories Co., Dayton, Ohio
DETROIT SECTION—B. Brede, assistant secretary, 1361 Book Building, Detroit
INDIANA SECTION—B. F. Kelly, Weidely Motors Co., Indianapolis
METROPOLITAN SECTION—F. E. McKone, 347 Madison Avenue, New York City
MID-WEST SECTION—T. Milton, 140 South Dearborn Street, Chicago
MINNEAPOLIS SECTION—C. T. Stevens, Reinhard Brothers Co., Minneapolis
NEW ENGLAND SECTION—H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston
PENNSYLVANIA SECTION—T. F. Cullen, Chilton Co., Market and 49th Streets, Philadelphia
WASHINGTON SECTION—B. R. Newcomb, 211 Victor Building, City of Washington

PROF. H. B. LEMON, of the University of Chicago, addressed the Mid-West Section on Feb. 3 on the subject of The Nature of Matter. Many of the very illuminating points he made were demonstrated by an unusually interesting series of laboratory experiments. The meeting was attended by several of the officers of the Society who were in Chicago in connection with the meeting of the Society held there earlier in the week. The large enthusiastic audience was given a great treat by being taken on a tour of inspection through several of the University laboratory departments. It is believed that the meeting inaugurated a helpful program of cooperation between the University and the Society.

The Metropolitan Section assisted the Society in the conduct of the Motorboat Meeting held at the Hotel Commodore, New York City, on the morning of Feb. 21. Com. Ernest Nibbs, formerly of the British Navy, gave a paper on The Development and Building of Diesel Engines and spoke of the fuel-saving possibilities of heavy-oil engines as compared with those using lighter fuels. R. B. Lea spoke of Compound Oil Engines for Marine Use, his talk being illustrated by lantern slides. Albert Hickman gave a sparkling address on Surface Propulsion in general and with particular reference to its use with the sea-sled type of hull. These papers, with the discussion which followed, completely filled the morning. Joseph VanBlerck presided at the meeting.

Following the technical session a luncheon was held at which William Washburn Nutting acted as toastmaster. Those who heard Nutting's account of his Transatlantic trip in the Typhoon at the Motorboat Dinner last year were not disappointed in his lively remarks at the luncheon. Dr. Walter E. Traprock, famous as the author of The Cruise of the Kawa, entertained the members and their guests with a narrative of his experiences while cruising in the South Seas.

Members of the New England Section who were not fortunate enough to be able to be on hand at the Motorboat Meeting in New York City were nevertheless able to attend a similar session in Boston on Feb. 24, when N. Warshaw presented a paper on Marine Engines. The meeting was preceded by a dinner at the Engineers' Club.

Increasing attention is being paid by the Sections to current economic conditions. The Pennsylvania Section on Feb. 23 listened to two most interesting speakers, Col. John Price Jackson, consulting engineer, at present retained by the Industrial Relations Committee of the Philadelphia Chamber of Commerce, who talked on What We May Expect in the Near Future in the Light of Today's Industrial Conditions and Basic Price-Movements, and E. J. Cattell, city statistician, who brought forth some new facts and figures and reasons for optimism regarding the future. In both of these talks consideration was given to the status of the automotive industry in the general situation and suggestions were made as to the part which the engineer should play in industrial betterment.

Schedule of Sections Meetings

MARCH

1—MINNEAPOLIS SECTION—Development in Automotive Transportation and Equipment—A. W. Scarratt

7—DAYTON SECTION — Some Aspects of Air-Cooled Cylinder Design and Development—S. D. Heron

17—NEW ENGLAND SECTION—Business Aspects of the Automotive Industry—H. W. Parlin.

21—BUFFALO SECTION—Electric Wiring Systems —W. S. Haggott

23—METROPOLITAN SECTION—Truck Rear-Axles—Ethelbert Favary

23—PENNSYLVANIA SECTION—Batteries and Electrical Equipment. Also paper by J. M. Teasdale

24—DETROIT SECTION

31—MID-WEST SECTION — Various Commercial Fuels and Their Relative Characteristics

APRIL

5—MINNEAPOLIS SECTION—Tractor Publicity and Demonstrations

21—METROPOLITAN SECTION - NEW ENGLAND SECTION—Joint meeting at New Haven, Conn. Inspection of laboratory equipment; and description of methods used in determining losses from the engine to the road, by Prof. E. H. Lockwood

21—DETROIT SECTION—Crankcase Dilution

27—PENNSYLVANIA SECTION—Commercial Motor Transportation

28—MID-WEST SECTION—Fundamental Losses in Automotive Apparatus

The Minneapolis Section arranged the excellent session held on Feb. 8 at which highway matters and the use of tractors in the building and maintenance of roads were discussed. It was also of invaluable assistance in the holding of the Society technical session and the dinner in Minneapolis on Feb. 9.

Coming Meetings

At the Dayton Section Meeting which will be held on March 7, S. D. Heron will present a paper on Air-Cooled Cylinder Design and Development. This paper is a very complete presentation of the subject, and is, in the opinion of a number of those who have seen the manuscript, one of the best papers ever given to members of the Society. The presentation of this paper at the March meeting of the Dayton Section is particularly fortunate since it will enable a number of the Society's officers who will attend the Council Meeting on that date to be present.

W. S. Haggott has in preparation a paper on Electric Wiring Systems, which he will give before the Buffalo Section on March 21. It is believed that this paper may possibly be used as a basis for standardization work along these lines, and members of the Electrical Equipment Division of the Standards Committee are particularly urged to attend.

CURRENT STANDARDIZATION WORK

LETTER ballots on adoption of the standards recommendations approved by the Standards Committee, the Council and the Society in annual meeting were sent to the voting members of the Society early in February. As these ballots will be counted on March 11, members should see that they reach the Society prior to that date.

The next issue of data sheets, which will contain the recommendations approved at the Annual Meeting, will be mailed to the members early in March. This issue will contain over 200 pages, the largest single issue representing current standardization work that has ever been sent to the members. The Iron and Steel Report covers 73 pages. Copies of this report will be available also in booklet form.

Members should see that the new issue of data sheets is correctly inserted in their S. A. E. HANDBOOKS so that they may be sure they have at hand the most recent revisions of all the S. A. E. Standards. An incident recently came to the attention of the office of the Society in which a bid was solicited on a quantity of material conforming to a certain S. A. E. Specification. The bid submitted was much lower than expected owing to the fact that it had been based on an obsolete copy of the specification covering that material.

The letter from the Society that will accompany the March issue of data sheets will contain a check-list of S. A. E. HANDBOOK data sheets. This will enable the members to check their S. A. E. HANDBOOKS so that they will be sure that they have all, as well as the most recent, data sheets issued to date.

The new issue of data sheets will bring the total number of pages in the S. A. E. HANDBOOK to 468. When it is appreciated that the standards as published by the Society are limited to the definite recommendations, no historical or explanatory matter being included, the large amount of work that the standards represent will be understood.

Information has been submitted to the members of each Division giving the status of the several subjects which have been assigned to the Standards Committee, together with lists of the personnel of the Subdivisions which have been appointed. Data in reference to subjects awaiting the consideration of any of the various automotive or parts and materials Divisions of the Standards Committee will be sent to interested members upon request.

INDUSTRIAL UNEMPLOYMENT

IT is estimated that, in 1920, the total number of persons engaged in gainful occupations in the United States was about 41,000,000. Most of the available employment statistics pertain to wage-earners in the groups of manufacturing and mechanical industries, which numbered, in 1920, about 12,800,000. During normal times, it is estimated, about 1,800,000 of these are out of work, since on the average about 42 days per year, or about 14 per cent of his total working time, is lost by each industrial wage-earner. The workers in many industries are subject to longer periods of unemployment, while in others the average is low. The unemployment situation has been abnormal due to business depression. It is estimated that over one-quarter of the industrial wage-earners were out of work on June 1, 1921, representing an estimated total of 3,500,000 persons.

There is need for a more adequate system of collecting and disseminating information showing the trend of prices, the actual cost of operation and the revenues from industry. Such a system will afford a reliable basis of comparison within plants at different times and between individual plants in the industry as a whole. The application of such methods to all industries will provide a kind of clinical thermometer of industry, which will afford a more trustworthy guide for judging future needs and prospects in the industrial system. The more the future situation can be anticipated, the more will it be possible to establish bases of control over normal production, distribution and consumption and over the fluctuations from prosperity to depression that recur at varying intervals of time.—From a report of National Industrial Conference Board.

PRODUCTION ORGANIZATION

THERE are two features that characterize all the systems of works records that really give satisfaction. In the first place they provide definite information on all matters upon which information is essential to the management, and they will also be found to have been developed in the particular establishment in which they are in force. These characteristics alone are sufficient to indicate the course to be adopted in any works in which it is felt that an existing system is inadequate or has outlived its usefulness. Instead of deciding to import somebody else's method, with the almost certain result of causing administrative indigestion throughout the factory, it is better for the manager to determine deliberately for himself, what are the exact questions upon which he wishes information to be available. It is a sound general rule that no fact is worth recording unless it may be useful as the basis of some executive act, either then or in the future. To acquire knowledge for its own sake is commendable in certain circumstances, but useless facts are worse than superfluous in the records of a firm. They involve time and expense in their collection, and discredit the system by smothering the wheat with valueless chaff. The decision as to what are the essential facts to be recorded is not one to be taken hastily, and the conclusion is likely to be different in different factories. When once it is made, there is established the beginning of a sound system of records which by reason of its simplicity and direct usefulness will be easily and sympathetically maintained by those upon whom its functioning depends.—*Engineering* (London).

S. A. E. Standards Exhibit at the Minneapolis Tractor Show

THE fifth annual exhibit of the Society at the National Tractor Show and Demonstration, held at Minneapolis during the week of Feb. 6 to 11, was of unusual interest and educational value. It consisted in part of large posters, making plain the current use of S. A. E. Standards in tractor construction, and specifying the standards that have been applied in the building of automotive engines and motor trucks. Two charts showed graphically and in figures the wholesale value of motor trucks and passenger cars produced in 1921, the saving attributed to the use of S. A. E. Standards in their production, and the cost of formulating S. A. E. Standards in 1921.

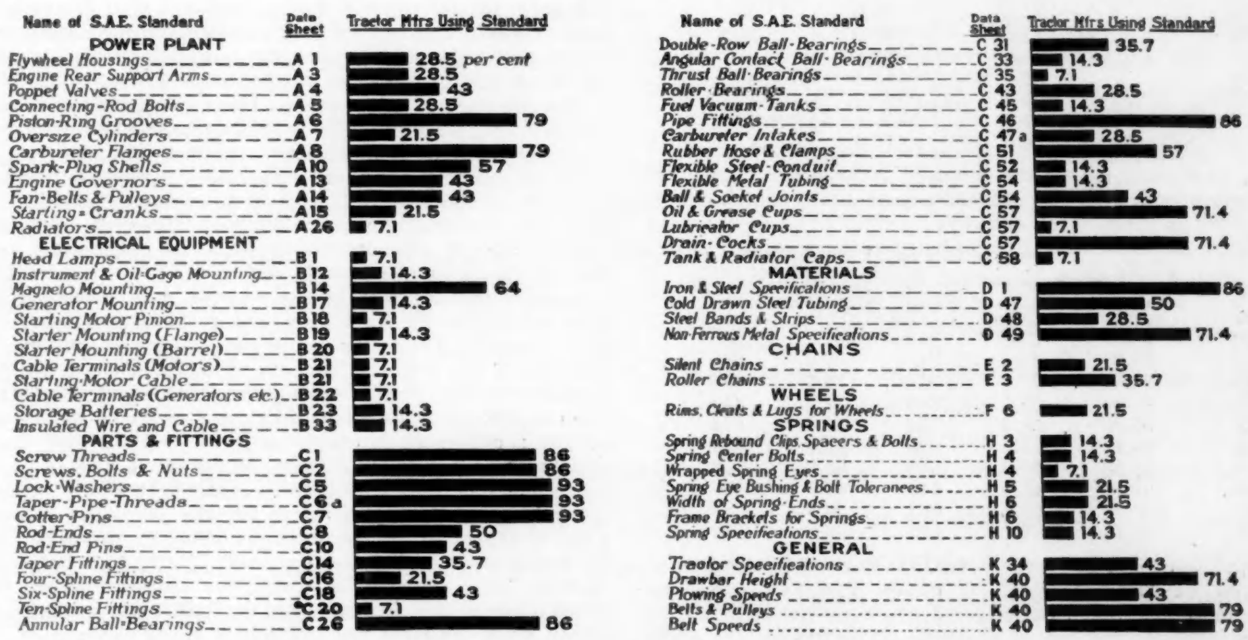


CHART SHOWING THE RELATIVE NUMBER OF TRACTOR BUILDERS USING THE 70 S. A. E. STANDARDS APPLICABLE TO TRACTOR CONSTRUCTION

Statistics that are considered reliable indicate this wholesale value to be $1,222,350,000, or 22,224 times the cost in 1921 of formulating S. A. E. Standards. The saving due to the use of the standards, based on an average of estimates made by nearly 150 prominent engineers and executives, amounted to 15 per cent, that is, $215,135,000, or 3911 times the cost of the 1921 standardization work. The estimated direct total cost of the Society's standardization activity during 1921 is $55,000.

The accompanying chart showing the respective percentage of tractor producers using various S. A. E. Standards is based on replies to a questionnaire sent to more than 100 companies in January.

A feature of the exhibit was six cartoons emphasizing practical reasons for and advantages of the reduction to practice of S. A. E. Standards as assisting directors of companies in planning production and helping a customer in difficulty, a car-owner in trouble, the dealer in stocking parts, the factory inspector in checking purchased parts and the tool and general production departments in reducing costs and equipment.

An important part of the exhibit consisted of more than 50 selected groups of different automotive parts, each a strictly commercial article, illustrating in concrete form the application of the standards in practice. These were arranged on long tables along the sides of the booth, and accompanied by the corresponding data sheets from the S. A. E. HANDBOOK.

The simple but thoroughly convincing nature of the exhibit was amply demonstrated by the interest shown by the large number of visitors, many of whom were agriculturists who had not previously known of the S. A. E. Standards. A number of these expressed the intention of talking with their local dealers regarding the desirability of incorporating as many of the standards as possible in the products they handle. Much information was disseminated in relation to the scope and work of the society, as well as its membership and several publications.

The Show afforded an excellent opportunity to obtain at first hand an insight into the rapidly growing appreciation on the part of builders and users of tractors and agricultural power-driven implements of the essential value of practical standardization and of the fundamentally important work the society is carrying forward through its widespread membership and the automotive industries in general.

DISTRIBUTION OF INCOME FROM PRODUCTION

CALCULATED in dollars the national income increased from $31,300,000,000 in 1910 to $66,000,000,000 in 1919, but calculating the value of the national product at 1913 prices the figures for 1919 are only $37,300,000,000, showing that the actual gain in product was only about 20 per cent, which is not much more than normal growth for 9 years. The figures for each of the years are as follows:

Year	National Income, billions of dollars	Weighted Index Number of Prices	Purchasing Power at Price Level of 1913, billions of dollars
1910	31.1	97.8	31.8
1911	31.2	98.5	31.6
1912	32.4	99.4	32.6
1913	33.3	100.0	33.3
1914	32.5	100.6	32.3
1915	35.9	102.5	35.0
1916	45.5	113.4	40.1
1917	53.9	136.1	39.6
1918	61.7	160.8	38.4
1919	66.0	176.8	37.3

The final estimate of the average income per capita and purchasing power at the price level of 1913, for the years from 1909 to 1918, is as follows:

		National Income		Purchasing Power at Price Level of 1913,	
Year	Population, millions	Income, billions of dollars	Per Capita Income, dollars	Income, billions of dollars	Per Capita Income, dollars
1909	90.37	28.8	319	30.1	333
1910	92.23	31.4	341	32.2	349
1911	93.81	31.2	333	31.7	338
1912	95.34	33.0	346	33.2	348
1913	97.28	34.4	354	34.4	354
1914	99.19	33.2	335	33.0	333
1915	100.43	36.0	358	35.2	350
1916	101.72	45.4	446	40.7	400
1917	103.06	53.9	523	40.8	396
1918	104.18	61.0	586	38.8	372

One of the most interesting results shows the division of combined net-value product of mines, factories and land transportation between earnings of employes and returns for management and the use of property. The figures are given in millions of dollars and also in percentages of the net value of the product, as follows:

Year	Wages and Salaries	Management and Property	Wages and Salaries	Management and Property
	millions of dollars		per cent	
1909	6,481	2,950	68.7	31.3
1910	7,156	3,250	68.8	31.2
1911	7,287	2,791	72.3	27.7
1912	7,993	3,169	71.6	28.4
1913	8,651	3,359	72.0	28.0
1914	7,947	2,816	73.8	26.2
1915	8,722	3,470	71.5	28.5
1916	11,630	5,810	66.7	33.3
1917	14,375	6,502	68.9	31.1
1918	17,472	5,124	77.3	22.7

The lesson to be found in this study of incomes is that they are governed by economic law, and not, as commonly assumed, by arbitrary power. They are not, in any general sense, within the control of employers, either singly or as a body, to fix as they please; nor can the general wage-level be materially changed by organization among wage-earners. There are certain relationships throughout industry, between the amounts disbursed for wages, required additions to capital, the share of the industrial product that shall be in the form of goods for current consumption and the share that shall be in the form of productive equipment, which in the long run are bound to be maintained. There is a balance, or equilibrium, in industry which must be maintained for the best interests of all; if it is disturbed, the normal exchange of goods and services is interrupted, and although wages may be nominally high they are actually low when taken into account. The latter is the state of things existing today not only in this country, but also throughout the entire world.

Wages must be high enough to enable the wage-earning class to buy and consume their normal share of the industrial product; otherwise products will accumulate and business will be bad. Likewise, farm products must have a purchasing power compared with other things that will allow the great body of people who live on the farms to take their usual share of goods, or unemployment in the other industries will result. Thus, every class, instead of being interested in fixing its own compensation without regard to the effect upon others, is interested in that right adjustment of values which enables the exchanges to be completely made, and in that manner serves the common interest.—National City Bank of New York.

HIGHWAY TRANSPORTATION AND THE AUTOMOTIVE ENGINEER

(*Concluded from page* 217)

hillsides. In Virginia a concrete road was built that held all right until the water got beneath it, which ruined the sub-grade and the road. It is worse than it was formerly, because the road is standing on edge.

MR. TEMPLIN:—It is no doubt true that the sub-grade has an important bearing on the success of the road. I do not wish to convey the idea that impact is the only destructive factor, because a defective sub-grade is another very important factor in road construction.

CHAIRMAN SMITH:—The Goodyear company has taken a broad-gage view of the situation; it makes tires and practically everything in the rubber line. Theoretically, it ought not to make much difference to the company what kind of tires it makes, but it is doing research work that is really worth while. We know that a bicycle weighing about 50 lb. will carry a load of 150 lb.; that a motorcycle weighing 150 lb. will carry 150 lb.; that a touring car is very poorly off in that a 4000-lb. car is designed to carry only about 300 lb.; and that a standard truck weighs approximately the same as its nominal pay-load. The Goodyear company has succeeded in producing a truck that carries a high ratio of pay-load to its weight and has been able to increase the operating speed. Speed is a commercial factor, always; in fact, it is a condition.

It is a pleasure to ride for 24 hr. on one of those six-wheel trucks and I have done this in a truck equipped with 12-in. tires with less fatigue than I have felt in some touring cars after a 10-hr. drive.

Applicants *for* Membership

The applications for membership received between Jan. 23 and Feb. 16, 1922, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, ROBERT A., general manager, Victory Hammered Piston Ring Co., *Newark, N. J.*

ANSCHUETZ, HARRY GEORGE, sales manager, Paul M. Marko & Co., *Brooklyn, N. Y.*

BEAUCHAMP, STAFFORD DUPONT, student, Georgia School of Technology, *Atlanta, Ga.*

BERRY, JOHN T., superintendent, Carriage Factories, Ltd., *Orillia, Ont., Canada.*

BILLMAN, H. C., instructor automobile mechanics, National Military Home, *Dayton, Ohio.*

BISHOP, WALTER W., JR., test engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

BLOMBERG, M., motor truck engineer, National Steel Car Corporation, *Hamilton, Ont., Canada.*

BORDEN, EDWARD ROY, mechanical engineer, Mudge & Co., *Chicago.*

BOUSE, MUREL R., instructor, Chanute Field, *Rantoul, Ill.*

BRAY, GEORGE H., assistant to supervisor of equipment, Texas Co., *Boston.*

BROOKS, HOWARD, assistant superintendent, American Smelters Securities Co., *Velardena, Mexico.*

BURLEY, HARRY B., president, Boston Insulated Wire & Cable Co., *Dorchester, Mass.*

CALDWELL, JESSE THOMAS, commercial engineer, National Lamp Works of General Electric Co., *Cleveland.*

CARSON, RAY EDGAR, student, Purdue University, *Lafayette, Ind.*

CASON, PAUL B., draftsman, Kimball Motor Truck Co., *Los Angeles, Cal.*

CHRISTIANSEN, SVEND A., test engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

CLARK, HAROLD EDMUND, motor-truck salesman, Packard Motor Car Co., *New York City.*

CLINE, N. N., student, Purdue University, *Lafayette, Ind.*

CRABILL, P. P., president and engineer, Central Brass & Fixture Co., *Springfield, Ohio.*

CROWELL, WILLIAM S., instructor, Y. M. C. A. Automobile School, *San Francisco.*

DALE, E. B., assistant professor of automotive mechanics, Colorado State Agricultural College, *Fort Collins, Col.*

DAVIS, FRED, engineering tests, General Motors Research Corporation, *Dayton, Ohio.*

DONAHEW, A. L., student, Purdue University, *Lafayette, Ind.*

EBERTS, JOHN FOSTER, student, Purdue University, *Lafayette, Ind.*

EYERLY, L. U., automotive engineer, 246 State Street, *Salem, Ore.*

FAUNTLEROY, HERMANZE EDWIN, student, Purdue University, *Lafayette, Ind.*

FAY, CHARLES R., student, Purdue University, *Lafayette, Ind.*

FIELD, BURNHAM E., metallurgical engineer, Union Carbide & Carbon Research Laboratories, Inc., *Long Island City, N. Y.*

FITZGERALD, EVERETT, Adirondack Power & Light Corporation, *Amsterdam, N. Y.*

GARDNER, ARCHIBALD D., student, graduate school of engineering, University of Michigan, *Ann Arbor, Mich.*

GRABNER, JOHN, student, Purdue University, *Lafayette, Ind.*

GRAPE, THEODORE S., manager and proprietor, Bearings Sales Co., *City of Washington.*

GRISELL, LOWELL HOBART, student, Purdue University, *Lafayette, Ind.*

HANNAH, WALTER JOHN, consulting engineer, Hannah King & Co., *Glasgow, Scotland.*

HARRIS, ELMER P., proprietor, Harris Mfg. Co., *New York City.*

HAZEN, RONALD MCKEAN, student, University of Michigan, *Ann Arbor, Mich.*

HEATON, HOWARD H., student, Purdue University, *Lafayette, Ind.*

HOLMES, H. GLENN, chief engineer, Novo Engine Co., *Lansing, Mich.*

HOYNE, BLANCHARD H., student, Purdue University, *Lafayette, Ind.*

HUBBARD, LEWIS EDWARD, student, Purdue University, *Lafayette, Ind.*

HUGHES, F. J., technical representative, Tilling-Stevens Motors, Ltd., *Maidstone, England.*

JOHNSON, E. F., general manager parts division, General Motors Corporation, *Detroit, Mich.*

KAPLAN, SIMON, sales manager, 1419 North Charles Street, *Baltimore, Md.*

KIRBY, MAJOR MAXWELL, Air Service, *City of Washington.*

MAGGS, ALBERT H., designing engineer, Ahrens Fox Fire Engine Co., *Cincinnati.*

MANN, ERNEST W., assistant engineer, Ward Motor Vehicle Co., *Mount Vernon, N. Y.*

METZROTH, WILLIAM, factory manager, Dyneto Electric Corporation, *Syracuse, N. Y.*

MILLER, ALBERT H., research engineer, Midvale Steel & Ordnance Co., *Philadelphia.*

MORTON, JENKINS JESSE, student, Purdue University, *Lafayette, Ind.*

PROVOOST, WILLIAM REES, draftsman, Tietjen & Lang Co., *Hoboken, N. J.*

PUHEK, MATT J., specification clerk, Dort Motor Car Co., *Flint, Mich.*

RAMSDALE, FRED, student, Pratt Institute, *Brooklyn, N. Y.*

RITZI, HARRY, student, Purdue University, *Lafayette, Ind.*

SCHAD, ALFRED BARTH, student, Purdue University, *Lafayette, Ind.*

SCHAKEL, RAYMOND ANTON, student, Purdue University, *Lafayette, Ind.*

SELLARDS, FRANK BOLTON, student, Kansas State University, *Lawrence, Kan.*

SOLBRIG, H. E., student, Purdue University, *Lafayette, Ind.*

SPRINGER, RUSSELL S., vice-president and factory manager, Holt Mfg. Co., *Stockton, Cal.*

STEEN, ADOLPH F., student, Purdue University, *Lafayette, Ind.*

STEPHENS, GEORGE H., chief engineer, Fansteel Products Co., Inc., *North Chicago, Ill.*

SWEET, WILLIAM M., vice-president, Klaxon Co., *Bloomfield, N. J.*

TAYLOR, JAMES RUSSEL, student, Purdue University, *Lafayette, Ind.*

TEETOR, IVAN, mechanic, General Motors Research Corporation, *Dayton, Ohio.*

THOMAS, THEODORE PAUL, student, Purdue University, *Lafayette, Ind.*

TODD, W. E. ARTHUR, Beaver Truck Corporation, Ltd., *Hamilton, Ont., Canada.*

TOLPUTT, HERBERT, manufacturer, Tolputt Co., *Sheffield, England.*

TUFFORD, HENRY HORACE, manager of tire instruction and supervisor of tire department, Dunwoody Institute, *Minneapolis.*

TUTTLE, J. H., chief engineer, Westcott Motor Car Co., *Springfield, Ohio.*

VAN ZANDT, FIRST-LIEUT. J. PARKER, Air Service, McCook Field, *Dayton, Ohio.*

WAINWRIGHT, J. DANIEL, Southern sales director, 643 Carondelet Street, *New Orleans, La.*

WENDELL, EVERT J., chief engineer and manager, Hale Fire Pump Co., Inc., *Conshohocken, Pa.*

WHITE, HERBERT R., general sales manager, Lancaster Steel Products Corporation, *Lancaster, Pa.*

WILFORD, J. W., general manager, General Products Co., *Detroit.*

WILLIAMS, GORDON HUNTER, student, Columbia University, *New York City.*

WILLIAMS, JOHN LEACH, assistant production manager, Canadian Products, *Walkerville, Ont., Canada.*

WILLIAMS, R. A., assistant supervisor of motor equipment, Texas Co., *Norfolk, Va.*

WINKLER, WILLIAM, owner, Winkler Motor Service, *Chicago*.

WINNER, CARL S., mechanical draftsman, Rock Island Arsenal, *Rock Island, Ill.*

WOOD, R. M., student, Georgia School of Technology, *Atlanta, Ga.*

WOODS, LEONARD R., salesman, Dorris Motor Car Co., *St. Louis*.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Jan. 10 and Feb. 10, 1922. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ACKERMAN, PAUL C. (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 327 Thompson Street.

AHLERS, MILTON THEODORE (A) assistant chief engineer, City Machine & Tool Works, *Dayton, Ohio*, (mail) 847 Bowen Street.

ALTHOUSE, ANDREW D. (M) instructor, Cass Technical High School, Detroit, (mail) R. F. D. 1, *Oxford, Mich.*

BENTON, EDWIN L. (J) service manager, Benton Electric Co., *LaCrosse, Wis.*, (mail) 112 North 10th Street.

BLACK, GEORGE A., JR. (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 624 Packard Street.

BOLGIANO, JOHN F. (S M) chief draftsman, transportation branch, balloon and airship section, Air Service, McCook Field, *Dayton, Ohio*.

BOSWORTH, ALVAH H. (A) vice-president and chief designing engineer, Colador Engineering Corporation, *Long Island City, N. Y.*, (mail) 8601 89th Avenue.

BURGER, GEORGE EDWIN, JR. (E S) mechanical engineer, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 1 Walnut Grove Place.

BURSIK, FRANK JAMES (E S) student, Armour Institute of Technology, *Chicago*, (mail) 1443 South Central Park Avenue.

BUSHNELL, SHERMAN W. (A) automotive engineer, 2515 Fourth Avenue, *Seattle, Wash.*

CANAVAN, J. JEROME (A) transportation engineer, 619 Chapman Building, *Los Angeles, Cal.*

CARTER, THOMAS FREDERICK (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 55 West North Avenue.

CHILMAN, CAPT. H. LEA (J) commercial transport consultant, 50 Daisybank Road, Victoria Park, *Manchester, England*.

CLARKE, JAMES RUSSELL (A) president, American-LaFrance Fire Engine Co., Inc., Elmira, N. Y., (mail) 250 West 54th Street, *New York City*.

CLARKE, LOUIS E. (A) sales manager, bearing and die-casting department, Hoyt Metal Co., Boatmen's Bank Building, *St. Louis*.

DAYTON, JOHN C. (A) engineer and manager, Dayton Gas & Electric Engineering Works, *Harrisburg, Pa.*, (mail) 1927 Logan Street.

ECKMAN, NORMAN H. (A) vice-president and general manager, Center-Fed Spring Insert Sales Co., Coal Exchange Building, *Wilkes Barre, Pa.*

EMERSON, L. A. (M) head of automotive department, William Hood Dunwoody Industrial Institute, *Minneapolis*.

FRANCIS, C. K. (M) chief chemist and technical superintendent, Cosden & Co., 1415 South Elwood Avenue, *Tulsa, Okla.*

GAUTHIER, EDWARD (J) mechanical draftsman, Holt Mfg. Co., 444 South Aurora Street, *Stockton, Cal.*

GELPKE, ADOLPH (M) chief draftsman, Autocar Co., *Ardmore, Pa.*

GRABOW, FREDERICK C. (J) designer, Shaw-Enochs Tractor Co., *Minneapolis*, (mail) 4600 Pleasant Avenue, South.

HEDRICH, O. H., JR. (E S) student, University of Illinois, *Urbana, Ill.*, (mail) 1204 West Green Street.

HOPKINS, FRED J. (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 164 West North Avenue.

HURD, RALPH H. (M) engineer, Libby & Huls, *Chicago*, (mail) 1323 West 98th Street.

HAMILTON, ERWIN (M) instructor in mechanical engineering, New York University; instructor in automotive engineering, United Y.M.C.A. Schools, *New York City*, (mail) New York University, 181st Street and University Avenue.

JOHNSON, ANDREW F. (M) instructor, Correspondence School for Automobile Body-Makers, Designers and Draftsmen, *Gray, Me.*, (mail) Gray, Me.

JONSSON, JOHN ERIK (E S) student, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 272 Hoosick Street.

KEIM, BYRON, L. (J) mechanical engineer, R. D. Nuttall & Automotive Parts Co., Pittsburgh, (mail) 1459 Foliage Street, *Wilkinsburg, Pa.*

KOELBLE, EDNA O'CONNOR (A) 370 Manhattan Avenue, *New York City*.

KOERBER, ARTHUR W. (M) draftsman, O. E. Szekely Engineering Co., Moline, Ill., (mail) 2831 Sixth Avenue, *Rock Island, Ill.*

LANGE, EDWARD C. (M) Pacific Power Implement Co., Foot of Jackson Street, *Oakland, Cal.*

LATHEM, JOSEPH GAULT, JR. (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 103 Ashby Street.

MALONE, D. G. (E S) student, University of Illinois, Urbana, Ill., (mail) 411 East Green Street, *Champaign, Ill.*

MESSINGER, CARL W. (A) sales representative, Stanley Works, New Britain, Conn., (mail) 1105 Kresge Building, *Detroit*.

MURPHY, JOHN EDMUND, 2ND (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 55 West North Avenue.

NEUHART, J. H. (A) general manager, Liggett Spring & Axle Co., *Monongahela, Pa.*

NOFSINGER, CHARLES W. (E S) student, University of Illinois, Urbana, Ill., (mail) 61 East Green Street, *Champaign, Ill.*

OHSAWA, GEN (E S) student, University of Illinois, Urbana, Ill., (mail) P. O. Box 525, *Champaign, Ill.*

PACKER, A. HERBERT (M) manager, P. R. Electric Starter Co., *Chicago*, (mail) 120 East 68th Street.

PARSONS, CHARLES EDWARD (M) chief engineer, Deppé Motors Corporation, 151 Church Street, *New York City*.

PETERSON, W. C. (M) metallurgist, Atlas Crucible Steel Co., *Detroit*, (mail) 5174 Parker Avenue.

PHELAN, HERBERT C. (A) tool salesman, Cornwell Quality Tools Co., Cuyahoga Falls, Ohio, (mail) 55 Spring Street, *Portland, Me.*

POWER, E. (M) superintendent of equipment, Union Oil Co., Union Oil Building, *Los Angeles, Cal.*

REINHARD, LOUIS (A) engineer, Geuder, Paeschke & Frey Co., *Milwaukee*, (mail) 709 Hackett Avenue.

ROOKS, ALFRED WENDEL (E S) student, School of Engineering, *Milwaukee*, (mail) 652 Milwaukee Street.

ROSECRANS, CRANDALL (J) research assistant, 102 Mechanical Engineering Laboratory, University of Illinois, *Urbana, Ill.*

ROWELL, HENRY SNOWDEN (F M) director of research, Research Association of British Motor & Allied Manufacturers, 15 Bolton Road, *Chiswick, London, W 4, England*.

RUGE, EDGAR P. (A) road service man, Dorris Motor Car Co., *St. Louis*, (mail) 5053 Kensington Avenue.

RYDER, C. D. (A) chief engineer, Corcoran Victor Co., Cincinnati, (mail) 320 Russell Street, *Covington, Ky.*

SCHROYER, E. C. (J) instructor, Georgia School of Technology, *Atlanta, Ga.*

SCHWARTZ, CHRISTIAN (M) testing engineer, research laboratory, Plant 5, Studebaker Corporation of America, *Detroit*.

SHOEMAKER, HARRY (A) salesman, Girard Automobile Co., *Philadelphia*, (mail) 6404 North 11th Street.

STROHL, GEORGE RALPH (M) mechanical engineer, Autocar Co., *Ardmore, Pa.*, (mail) 520 East County Line Road.

STURTEVANT, FOSTER E. (J) draftsman, Ward Motor Vehicle Co., *Mount Vernon, N. Y.*, (mail) 45 South First Avenue.

TETHER, CLIFFORD F. (E S) student, Rensselaer Polytechnic Institute, *Troy, N. Y.*, (mail) 145 Eighth Street.

TILDEN, SYDNEY G. (J) in charge of wholesale sales, Vandar Motor Sales Corporation, Brooklyn, N. Y., (mail) 223 Woodland Avenue, *New Rochelle, N. Y.*

TRAMMELL, LEANDER NEWTON (E S) student, Georgia School of Technology, *Atlanta, Ga.*, (mail) 55 West North Avenue.

ULRICH, THEODORE (J) layout draftsman, Hupp Motor Car Corporation, Milwaukee and Mount Elliott Avenues, *Detroit*.

VIETS, ELTON WILLARD (E S) student, University of Michigan, *Ann Arbor, Mich.*, (mail) 624 Packard Street.